INDIA – THE LAND AND PEOPLE

PLANT DISEASES

R. S. MATHUR

NATIONAL BOOK TRUST, INDIA

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R.S. Mathur
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PLANT DISEASES

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R. S. MATHUR

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FOREWORD

WITH so much emphasis on food production in our country, the problem needs to be tackled at all levels and from various angles. We require new methods of agriculture, better seeds, effective manure and constant irrigation facilities. But all this can be undone by any unfortunate plant disease. Eradication of disease is essential for agricultural progress.

The unique quality of this book is that Dr. Mathur, a distinguished expert, has discussed plant diseases, often shrouded in mystery to laymen, in a lucid style and simple language which can be easily understood by the non-specialist. Latest information provided on the control of plant diseases would be equally useful to administrators, teachers and students as also to extension workers and farmers.

NEW DELHI — B. V. KESKAR

February 20, 1969

INTRODUCTION

As a great hazard to Indian agriculture, plant diseases often make newspaper headlines. It is estimated that more than Rs. 400 crores of our national income is lost annually due to plant diseases caused by fungi, bacteria, nematodes and viruses. Considerable loss is also reported from unthrifty production due to malfunctioning under industrial fumes, high acidity or alkalinity of soil or unfavourable conditions of storage and marketing. According to the 1965 Production Yearbook of the FAO, plant diseases account for 12% reduction in the potential crop production equivalent to approximately 24,800 million dollors ($ 1.00=Rs. 7.50). Some plant diseases are highly infectious so that in years of epidemic, there may be a total failure of crops in certain areas.

Man's subsistence and amenities depend on healthy plants capable of the highest possible yields. Of all the measures suitable for increasing crop yields, modern crop protection methods are the fastest and least expensive. A producer or consumer feels quite concerned about knowing the field symptoms of important plant diseases as well as their nature, prevention and control. This book aims at fulfilling these needs of the common man.

The contents of the book are based on the author's long experience and the published results of hundreds of plant pathologists in India and abroad. A lucid style and simplicity of expression have been maintained throughout the book so that the common educated man may derive the maximum benefit from a practical knowledge of plant diseases and their control. The use of trade names of chemicals and machinery has been adopted mainly to provide specific information and should not be considered as a guarantee against others of similar specifications. More information on the active ingredients, uses and cost of application can always be had

directly from the distributors of proprietary chemicals and machines and regional offices of plant protection services in India.

Thanks are due to Dr. Jagdish Swarup for his willing cooperation in verifying the published results of practical value, to Mr. P. Banerji for preparing coloured plates and the line drawings and to Mr. Ganga Prasad for typing the manuscript.

R. S. MATHUR

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(f=facing)

CHAPTER I

PLANT DISEASES MAKE HISTORY

GREEN PLANTS, being synthesizers of food from elementary substances and solar energy, support all other forms of life—man, animals, insects, tiny bacteria and even invisible viruses. Our food from animal sources (meat, poultry, eggs and milk) can also be traced to fodder and feed plants on which cattle and birds depend totally. Hence the health of plants is vital to society and human progress. Where the population density of human beings is over 500 per square mile, great care has to be exercised to control common ailments and prevent the development of epidemic diseases. In comparison, an acre (0.001563 square mile) of a wheat field may contain about 100,000 plants of a single variety grown under conditions of high fertility and irrigation—an ideal environment for the devastating attacks of plant pathogens. If agriculture is to progress, the disease problems must be tackled successfully.

Plant diseases began to foil man's attempt to feed and clothe himself almost as soon as he started cultivating plants. There are frequent references to the devastation of crops by epidemics of diseases in the Vedas, the Bible and other ancient writings of the Hebrews, the Greeks and the Romans. The Hebrews ascribed the calamitous plant diseases to the wrath of God whom they tried to appease by prayer and righteous living. The ancient Greek farmer who depended on the phases of the moon for his farm operations sought the mercy of Apollo to save his crops from pests and diseases. The Romans believed in Robigus, the god of the cereal rusts, whom they tried to please by the opening prayer, "Stern Robigo, spare the herbage of the cereals; withhold, we pray thy toughened hand...". The prayer was followed by an annual procession of white-robed Romans through Porta Catularia and Claudia to a sacred grove where a yellow dog was sacrificed. In the Middle Ages, the ergot of rye became so prevalent that many people, who

ate the ergot-infected bread, lost their limbs with dramatic suddenness and bizarre stories of their sufferings are still read with horror.

The French observed that the rust of cereals was ruinous in the vicinity of barberry bushes. In 1660, a law was passed in Rouen to eradicate barberry bushes near wheat cultivation in order to minimise rust attack. This was the first rational attempt at controlling a plant disease.

The compound microscope was invented in 1590 but Leeuwenhoek saw the micro-organisms and illustrated them about a hundred years later. The evidence for the causal relationship between a fungus and a plant disease came two centuries later in 1850 with de Bary's demonstration that the fungus *Phytophthora infestans* de Bary[1] caused potato late blight. Under a holocaust of late blight in Europe and a major potato famine in Ireland in 1845 when nearly a million people died and a million and a half emigrated to far-off countries, de Bary's discovery marked the beginning of modern plant pathology. That bacteria and viruses could also cause plant diseases was reported a few decades later. The development of rational methods of control measures has been possible during the last fifty years only.

In relatively recent times also, plant diseases have made history. Before 1880, the ravages of coffee rust in South-East Asia were so serious that the cultivation of coffee had to be abandoned and the world's coffee production shifted from Ceylon to Brazil. Sugarcane diseases in Asia, Africa and parts of South America have lately accounted for a loss of 42.8% of the actual production and the potential wheat production in the former British African colonies was reduced by 25.8% chiefly by rusts. The *Helminthosporium* blight of rice was one of the major causes of a famine in Bengal in 1943 in which 50 to 90%

[1] This is the name given by de Bary to the fungus which caused late blight in potatoes. Such binomial Latin names, first of the genus and second of the species, are used internationally for all plants and animals.

of the crop was destroyed. Wheat rusts, paddy blast and sugarcane red rot still continue to be national problems of high priority in India. In Ghana and Nigeria, the most serious disease of cacao plantations is the swollen shoot virus disease. The blue mould of tobacco was responsible for a monetary loss of 25 million dollars in 1960 and 88 million dollars in 1961 in Europe. Although catastrophic epidemics of plant diseases occur periodically in various parts of the world, the annual losses, evident and hidden, result in the wastage of tremendous quantities of human food which never reach the consumer.

Forty years ago, Professor H. H. Whetzel, a noted American plant pathologist, wrote as follows about a city man's concern about plant diseases :

"..... The city man, therefore, is most concerned in the devastation wrought in crops on which he depends for food, shelter, or clothing. For every two sweet potatoes which are brought to him at the restaurant, he pays for one he does not get. On the average one sweet potato out of three produced in the United States is lost from disease in field or storage house. In every half-dozen cotton shirts a man buys is included the cost of a seventh one lost to diseases in the cotton fields of the south...".

Much of the present loss due to plant diseases can be reduced by the active cooperation of the layman with the specialist. Governmental Plant Protection Services are available to him throughout India upto the Block Development level. The chapters that follow will provide him with the basic knowledge about the field identification and rational control of some of the major plant diseases commonly met with in India.

CHAPTER II

SYMPTOMS, CAUSES AND CONTROL

PLANTS FURNISH us with food, clothing, shelter, drugs and hundreds of manufactured articles. Anyone who grows plants wants them free from diseases. A practical concept of a plant disease is that a plant should be so impaired as a whole or in any of its important organs that its usefulness to itself or to mankind is seriously affected. Thus it is important for the grower to recognize the signs and symptoms of the sick plant. By closely looking at the diseased portions with the help of a pocket lens, such signs of the disease as the white, brown or dark thread-like structures of the fungus (mycelium) and bright or dark coloured fruiting bodies can be detected. Talc-like powder on the leaves of plants is a sign of powdery mildews, whereas crusts of dark mycelium on leaves or stems are signs of sooty moulds. A foul-smelling ooze pressed out of the decaying tissues signifies the presence of bacteria. Symptoms show changes in the structure or function of the affected plant and their study is the first step in diagnosing a disease. Mottling, crinkling or mosaic patterns of green and yellow observed in leaves held against sunlight are symptoms of a virus disease. When a layman holds the smut whip of sugarcane or the loose smut-affected ears of wheat, his fingers are smeared with a black powder. While entering a severely rust-affected field, one usually finds one's clothes soiled with yellow powder of rust spores. These diseases are relatively easy to identify. But sometimes the living agents of diseases (plant pathogens) and non-parasitic disturbances cause such a diversity of symptoms in plants that the grower must consult a trained plant doctor (plant pathologist) for the correct diagnosis of the malady. Once the disease is diagnosed and its cause determined, its control becomes logical and easy.

SYMPTOMS

A disease is expressed in a definite series of symptoms which

may be localized as in the case of leaf spots, scab and fruit rot or it may be systemic when all parts are affected as in the case of *Fusarium* wilts and virus diseases.

Symptoms of plant diseases can be divided into three broad categories : necrosis (Gk. *nekrosis* from *nekroun*=to make dead, mortify); hypoplasia (Gk. *hypo*=under+*plasis*=formation or undergrowth) and hypertrophy (Gk. *hyper*=over+*trophe*=food, *i.e.*, overgrowth). Thus necrosis is the death, rotting or decay of tissues; hypoplasia is under-development and hypertrophy is abnormal overgrowth.

Self-limited or local necrosis can be observed in leaf or fruit spots and certain kinds of cankers. General necrosis, mostly associated with fungi, can be seen in root rots, collar rot or rotting of fruits, tubers and bulbs. Plant residues or plant products during storage or marketing may rot and decay by the action of fungi and bacteria.

Examples of stunting and dwarfing by hypoplasia are common to many virus diseases, *e.g.*, potato mosaic and tomato leaf curl and mosaic.

Hypertrophy or abnormal growth is often met with in the bacterial crown gall of many kinds of plants, *e.g.*, tomato, apple, etc. Cabbage club root, peach leaf curl, white pine blister rust and white rust of crucifers are hypertrophic diseases caused by fungi. Cotton crazy top, showing swellings and abnormal growth of leaves, is due to 2,4-D weed killer spray. Root knot by tiny eelworms (nematodes) or the formation of root nodules by nitrifying bacteria are other examples of hypertrophy.

Sometimes plant diseases are grouped by the similarity of symptoms on a number of host plants, *e.g.*, downy and powdery mildews, rusts and smuts. Often the symptoms are grouped on the basis of parts of plant affected : grain smut, seedling blight, wither tip, blossom blight, and root, tuber, bud or fruit rot. Die-back is a general term for any condition in which shoots and branches die slowly, beginning from the tip backwards. It may be due to some viruses, malnutrition or poor

soil and drainage. Specific examples of symptoms characteristic of some major diseases will follow in subsequent chapters.

Causal Agents

Plant diseases are caused both by living and non-living agents. When they are caused by living agents, they are called parasitic diseases; when they are due to non-living causes, they are grouped under non-parasitic diseases. The living agents are viruses, bacteria, fungi, nematodes and parasitic seed plants. A lone green alga *Cephaleuros mycoidea* causes red rust of tea. It also infects mango, guava and other economic plants. The non-living agents of plant diseases are unfavourable soil and meteorological conditions, mechanical and chemical injuries due to faulty agricultural practices, or industrial by-products and products of plant metabolism especially in transit and storage.

Viruses are living entities but because some viruses have been crystallized like common salt, the virus particles are also considered non-living. Now-a-days viruses are accepted as living entities and the crystalline virus particles as their dormant stage. The virus particles are extremely tiny and cannot be seen by the ordinary compound microscope. An electron microscope is used to photograph their structure which is magnified 200,000 times. The needle-like rods of tobacco mosaic virus measure 15 $\times$ 300 mμ (1 mμ=0.000,001 mm.).

The mode of infection of viruses has been demonstrated in a virus that infects bacteria (bacteriophage). The tadpole-shaped bacteriophage injects DNA (desoxyribonuleic acid), coiled in the head, directly into the bacterium, leaving the protein coat behind. The nucleic acid then directs the production of hundreds of virus particles within the bacterial cell which bursts and releases these particles into the medium. Whereas the DNA is confined to the nucleus and associated with genes which are the bearers of heredity, RNA (ribonucleic acid) is commonly found throughout the cells of all kinds of plants. Recently the India-born Nobel Prize winner,

Dr. H. G. Khorana, synthesized DNA making it possible to codify the messages of heredity in the offspring. This opens up possibilities of controlling genetic diseases. Viruses, however, enter the plant only through mechanical injury or wounds caused by insects. Aphids and white flies transmit the largest number of plant virus diseases. An agent which transmits disease is called a vector.

Bacteria average $1—3 \times 0.5\ \mu$ ($1\ \mu$=0.001 mm.) in size and multiply every 20 to 30 minutes by a simple transverse division into two equal parts. They infect plants by entering through mechanical injuries, leaf pores (stomata) and water pores (hydathodes). They produce rotting enzymes and wilt toxins to destroy and decay plant tissues and survive in a gelatinous ooze. A pictorial representation of the life cycle of citrus canker—a bacterial disease—is given in Fig. 1.

Fungi incite the largest number of devastating diseases or spoilage of agricultural products. There are some 50,000 parasitic (Gk. *parasitos*=eating beside another) and even more saprophytic (Gk. *sapros*=rotten +*phyton*=plant) fungi reported throughout the world. Whereas the rusts, smuts and powdery mildews compulsorily attack living plants, there are other pathogens which live successively on dead plants and living plants. They produce a variety of tiny seeds called spores which adopt different methods of dispersal and infection. Fungi and bacteria survive in many different ways but usually by means of thick-walled spores. The spores are packed securely in fruiting bodies which may look like hard rind or thick-walled balls, flasks, cups and saucers. The mushrooms have gills—folds of thin fertile layers to which innumerable colourless (hyaline) or coloured spores are attached. The rust spores are packed in blister-like tiny pustules and are dispersed by the rupture of the outer skin (epidermis) of leaves and stem. The grains of cereals and grasses are replaced by a black powder of spores and this condition is noticeable in loose or covered smut or grain smuts of cereals and millets. In the flag smut of wheat, longitudinal leaf pustules are filled

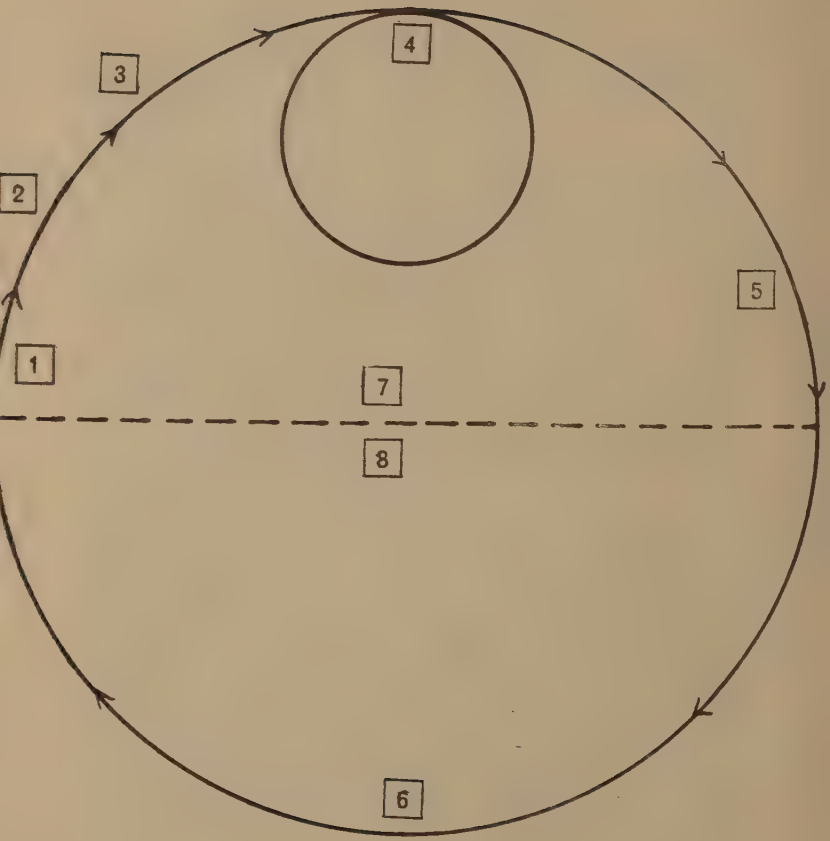

Fig. 1—Life cycle of bacterial citrus canker.

1. Bacteriai ooze from cankers 2. Blossom infection via rain,insects 3. Pathogen multiplies 4. Secondary infection of blossoms, fruit, leaves, twigs etc. 5. Twig and leaf cankers 6. Dormant cankers 7. Active 8. Dormant

with dark smut spores.

The number of infective spores produced by fungi is enormous. In an acre of severely rust-affected wheat, there may be 50,000 billion spores and clouds of this rust dust can be seen rising into the air while harvesting a wheat field.

During the life-cycle of a fungal parasite, several kinds of spores, some for infection, others for survival, may be formed on one or two hosts. The host relation of *Phytophthora infestans*, the fungus which causes the late blight of potato, is diagramatically shown in Fig. 2. The wheat black rust fungus produces five different kinds of spores and spends its life-cycle on two different host plants, *i.e.*, wheat and barberry. The life-cycle of the root knot nematode, a tiny eelworm scarcely visible to the naked eye, is shown in Fig. 3. Seeing is believing. Hence a layman's visit to a Central or State Agriculture Department's Plant Diseases Museum and Laboratory would be helpful to him in finding out for himself the distinguishing symptoms of diseases and observing under the microscope the structures of the living agents invisible to the naked eye.

As regards non-parasitic diseases, the American Potash Institute published a useful key to nutrient deficiency symptoms. Coloured charts are also available by which symptoms of deficiency or hunger for nitrogen, potassium, phosphorus, zinc, copper, boron, manganese, etc., can be made out and remedial measures taken according to the advice of a specialist.

Epidemic Diseases and Forecasting

A producer or consumer is not so much concerned with the sickness of an individual plant. But when disease epidemics destroy large populations of plants like the epidemics of plague, small-pox and cholera in human beings, there is cause for alarm. If impending calamities of this kind are predictable, necessary precautions can be taken to fight the epidemic. Scientists have determined the conditions of epidemics at least in the case of a few diseases which can be forecasted to permit timely control measures. Three conditions must be fulfilled

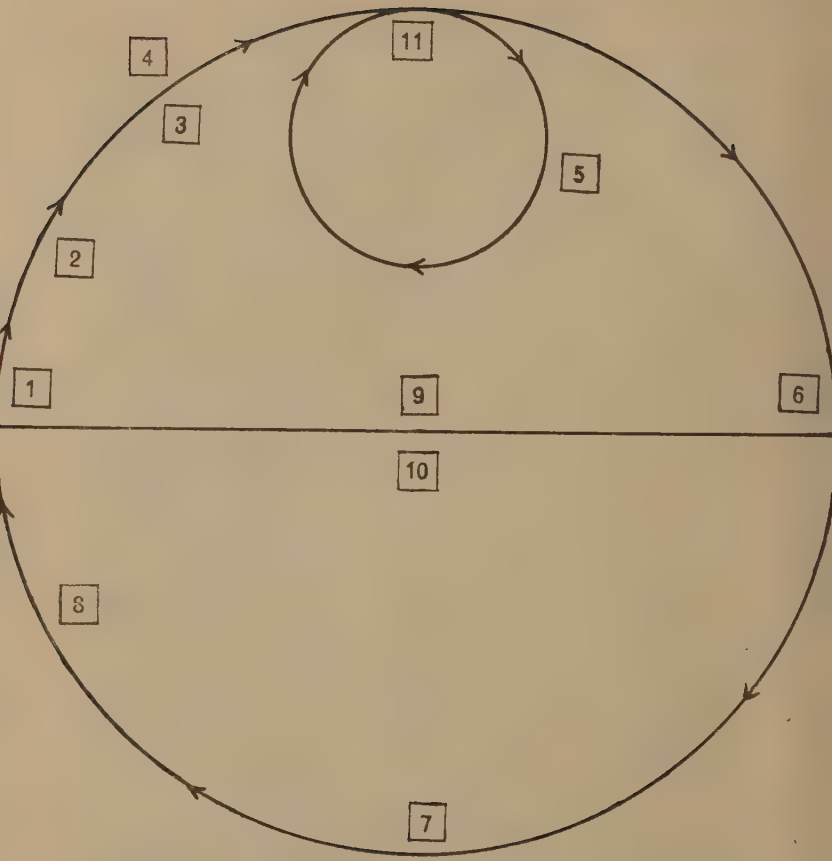

Fig. 2—Life cycle of the potato late blight fungus.

1. Infected tubers 2. Pathogen spreads in stem 3. Foliage infection
4. Pathogen multiplies 5. Spores 6. Infection of tubers
7. Infection tubers stored 8. Mycelium dormant in tubers
9. Active 10. Dormant 11. Secondary infection

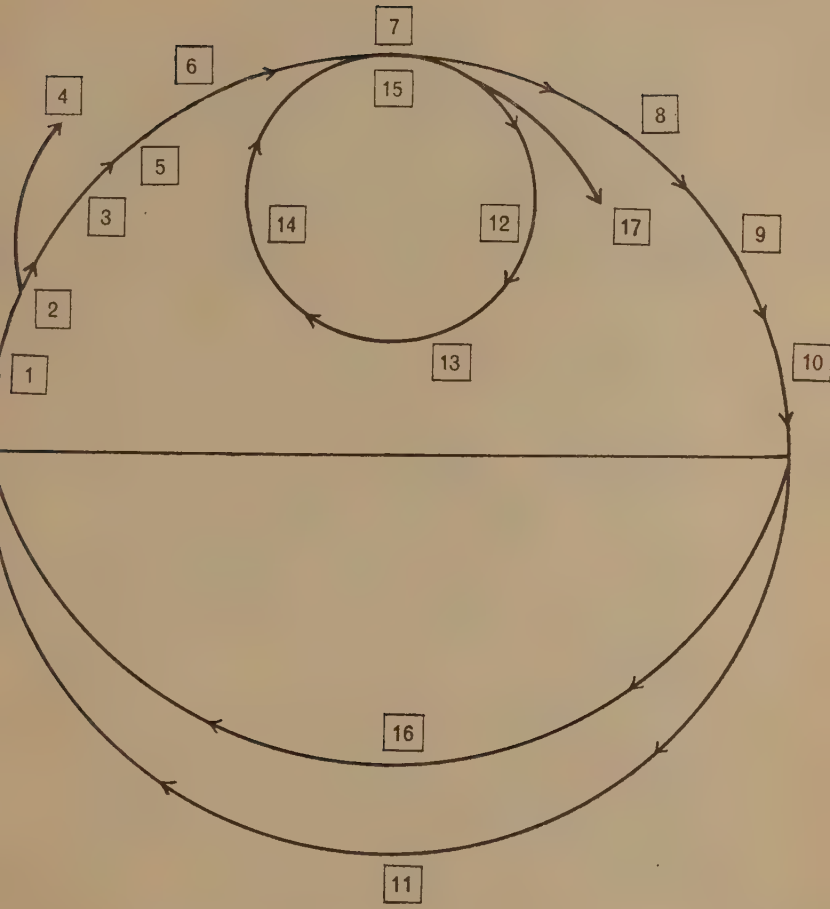

Fig. 3—Diagramatic representation of life cycle of Root knot nematode.

1. Infection larvae in soil 2. Infection 3. Female 4. Male 5. Eggs 6. Infection larvae 7. Infection 8. Female 9. Eggs 10. Larvae 11. Larvae and eggs in plant 12. Female 13. Eggs 14. Infection larvae 15. Secondary infection 16. Larvae in soil 17. Male

before an epidemic can be initiated: (1) susceptible host plants are spread over a large area; (2) a virulent strain of the parasite is widespread, and (3) there are favourable weather conditions for the spread of the disease. If only two conditions are fulfilled, there can be no epidemic as shown in Fig. 4. The potato late blight develops most quickly when cool, wet nights alternate with warm and moist days. Under such conditions the infective spores of the parasite (*Phytophthora*

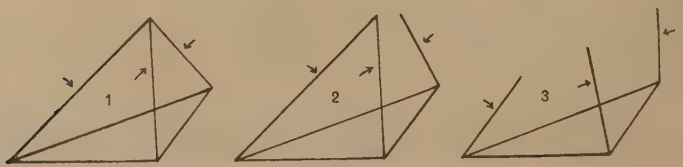

Fig. 4—Three conditions must be fulfilled for the development of an epidemic :

(1) General prevalence of pathogen (2) high population of susceptible plants (3) favourable weather (After Melhus and Kent, 1939).

infestans) germinate at 12°C to 13°C and the fungus grows and sporulates between 22°C and 24°C.

Forecasting services for the potato late blight, tobacco blue mold and cucurbit mildew are available in the U.S.A. and for paddy blast in Japan. Regional forecasting on the basis of instrumental recording in crop fields is a promising future development in India because the farmers can recover at least part of their season's investment by timely spraying of chemicals.

Control of Plant Diseases

Both temporary and permanent control measures against plant diseases are practised today. Modification of agricultural practices such as change in date of sowing, sanitation, etc.; use of disease-free seed and propagating stock of horticultural plants; seed treatment before sowing, spraying and

dusting of standing crops with fungicides; impregnation of poles, timber, hessian cloth and textile, etc., with chemical preservatives and chemically-treated wrappers for fruits in transit and marketing are some of the plant disease control methods which are practised as a temporary measure in order to prevent rotting and weathering and the appearance of plant diseases or if they have already appeared, to prevent their spread to healthy plants. Of these methods, chemical methods are the fastest, easy to manipulate and low in cost. Permanent or semi-permanent control measures include enforcement of plant quarantines, eradication programmes and breeding for disease resistance. Where intensive programmes of plant protection are carried out, real harvest failures are seldom noticed. Because the operating cost of cultivation remains the same, harvest losses due to plant diseases will always directly lower the net return. If, for example, the net income amounts to 20% of the gross receipts, a 10% loss of the gross income will mean a 50% decrease in net return; a 20% loss will completely diminish the net return. Therefore, it is advisable to incur small expenses on plant protection.

CHAPTER III

DISEASES OF CEREALS

CERES WAS the corn-goddess of the Romans. Derived from Latin, cereals mean edible grain of all kinds. Since the dawn of civilization, the cereals — wheat, barley and rice—have formed the major portion of the human dietary requirements, and as such have always influenced the imagination of rural people for profitable farming. Ancient Egyptian writings, the Vedas and the Bible show that major diseases of these crops were already known since very early times although exact diagnoses were not always possible. The familiar names of diseases such as rust, smut, blight, blast and mildew still tax man's power of observation when he is robbed of a substantial portion of his crop annually. It was estimated in 1958 that the total annual loss in the world's grain crops, due to pests (including diseases), amounted to 33 million tons, sufficient to feed 150 million people for a year. The layman should, therefore, be interested to know the symptoms by which he can recognize and distinguish these diseases and learn to apply control measures intelligently. The specialist must help alleviate the food problem by devising new control methods and improving the old ones.

RUSTS AND SMUTS OF WHEAT AND BARLEY

Rusts of Wheat and Barley : As a result of rust attack, recognized in the field by the rusty appearance of the crop due to the formation of innumerable rust pustules, the grains are shrivelled and the straw becomes worthless for fodder. Wheat is attacked by three kinds of rust — black, brown and yellow — and barley also by three kinds of rust — black, dwarf and yellow — and each rust has a number of pathological strains called physiological races which show different infective capacities on different wheat or barley varieties. In India, a total of 57 physiologic races of rusts of wheat (black 23,

brown 20 and yellow 14) and 41 physiologic races of rusts of barley (black 23, yellow 14 and 4 races of dwarf rust) have been found. This complicates the breeding programme for evolving wheat and barley rust-resistant varieties and requires concerted action of scientists belonging to different fields of specialization. The annual loss due to wheat rust in India is estimated at 6 crores of rupees.

Salient features by which the three rusts of wheat are recognized in the field are given in Fig. 5 and Table 1.

Annual Recurrence : How wheat rusts appear every year on the plains of India when the infective spores cannot survive the summer heat has engaged the attention of Indian scientists for a long time. At one time it was thought that the eradication of barberry would help in eliminating the devastating black rust from India. But subsequent research has shown that the particular species of barberry on which the black rust fungus completes its life-cycle in Europe and the United States of America does not occur in India and, therefore, the annual recurrence of this fungus in the plains is caused by spores blown about by wind from the hills where it oversummers on self-sown wheat plants in a cooler atmosphere. Commercial wheat crop is grown in the plains during winter and viable (Lat. *vita* = life) rust spores, blown about by air currents from the mountains, settle down on it, cause new infections and spread the disease. With the help of vaseline-smeared glass slides attached to balloons filled with hydrogen and released high up in the atmosphere, rust spores have been caught at least six weeks before the outbreak of rusts on the plains. This knowledge is helpful in forecasting rust epidemics and taking timely measures to prevent impending losses. Factors which often contribute to the development of wheat rust epidemics are : oversummering of rust spores on self-sown wheat plants, appearance of new physiological races, mass air movements dispersing infective spores over large areas, time and abundance of initial infection, and prolonged periods of warm, moist weather.

TABLE 1

Showing Salient Distinguishing Features of the Three Rusts of Wheat

Stem rust or black rust caused by *Puccinia graminis tritici*	Brown, orange or leaf rust caused by *Puccinia recondita*	Striped or yellow rust caused by *Puccinia striformis*
1	2	3
In northern India black rust appears in March ; in southern and peninsular India by end of November.	Appears more commonly in northern and eastern India in January. Together with yellow rust causes much loss in Punjab, Uttar Pradesh and Bihar ; rare in southern and western India.	Appears early in January ; confined to northern and eastern India.
Oblong reddish brown lesions merge into one another, prominent on stems, leaves, leaf sheaths and glumes.	Scattered pustules of orange colour are confined to leaves.	Rust pustules of lemon-yellow colour containing yellow mass of spores are arranged in long streaks, confined to leaves ; in case of severe attack, they may appear on leaf sheaths, stalks and glumes also.

In India, fungus oversummers on self-sown wheat plants on hills at an altitude of 1524 m. (5,000 ft.) or above.	Oversummers like black rust.	Oversummers at still cooler temperatures on hills at altituders of 2134 m. (7,000 ft.) or more.
Fungus spends life-cycle on wheat and barberry (*Berberis vulgaris*), called alternate host. Role of *Berberis* spp. and *Mahonia* is not important in rust outbreaks in India.	Alternate host of leaf rust in India is *Thalictrum flavum*, but its role in rust outbreak is not important.	Alternate host of yellow rust is not known.
Some grasses harbour the fungus, e.g., *Briza minor* which spreads the disease in Nilgiri and Pulney hills in southern India ; *Bromus* spp. spreads it in Northern India.	Brome grasses spread the disease in Europe and U.S.A. and possibly in India.	

Control : The best method of controlling rust is to use rust-resistant wheat varieties. Resistance to rusts is governed by genetical factors. Because the particular species of barberry, responsible for the origin and multiplication of a large number of physiological races as are found in Canada and the U. S. A., is not found in India, the task of breeding rust-resistant wheats is not too difficult though it is sufficiently complicated. The Indian Council of Agricultural Research was founded in 1930 on the recommendation of a royal commission headed by Lord Linlithgow, a former Viceroy of India. One of the first projects financed by this Council was to investigate cereal rusts and evolve rust-resistant wheat varieties for India. This work still continues to be of national importance. Some of the rust-escaping varieties which are recommended for general cultivation are : NP. 829 for lower hills of Northern India (altitude 914 m. or 3,000 ft.); NP. 809 for medium elevations of Northern India (altitude 914—1829 m. or 6,000 ft); NP. 824 for Delhi; NP. 798 for Bihar, West Bengal, Eastern Uttar Pradesh, Gujarat and Orissa ; NP. 792 for parts of Himachal Pradesh (Paonta valley); NP. 718 and RS. 31-1 for Rajasthan; NP. 200 for the Nilgiris and the Palni hills ; C. 281 and C. 273 for the plains of Eastern Punjab; C. 285 for the Punjab hills, and Hy. 65 for certain parts of Madhya Pradesh (Narmada valley).

After the recent drought years and acute food shortage, the dwarf Mexican varieties of wheat such as Sonara 64, Kalyan sona, Sonalika (S. 308), Choti Lerma (S.307) and Safed Lerma (S.331) are coming into general cultivation on account of their tolerance to rusts and high-yield potential.

Chemical control of cereal rusts can be resorted to on commercial crops when there is danger of rust appearance in a severe form. As soon as rust symptoms appear, the crop should be sprayed three or four times with dithiocarbamate fungicides, at the rate of 3 kg. per hectare such as Dithane Z-78, Dithane M-22, Dithane S-31 or wettable sulphur, viz., Thiovit dissolved in 800 to 1000 litres of water per hectare (1 hectare

= 2.47 acres) in the conventional type of sprayers such as Maruti Foot Sprayer manufactured by M/s. American Spring and Pressing Works, Bombay. When low volume knapsack sprayer such as Aspee Bolo Motorised Mist Blower-cum-Duster is to be used, this quantity of fungicide is dissolved in 250 litres of water and sprayed. Alternatively, 2-3 dustings with 300 mesh sulphur dust at 17 kg. per hectare is also recommended to control rust severity.

If cereal rust epidemics are to be checked, growing field resistant wheat varieties in the hills and controlling secondary spread of rust by chemicals on the plains can be a practical and economical way of minimizing losses.

Smuts of wheat and Barley : Grain worth crores of rupees is destroyed by smuts every year throughout the world. In India, smuts often destroy 30 to 50 per cent of cereal crops in cultivator's fields where attention is not given to their control. For purposes of study and control, the smuts can be grouped into seedling-infecting and floral-infecting types.

In the seedling-infecting smuts such as stinking and flag smuts of wheat and covered smut of barley (Fig. 6), smut spores get smeared on the surface of the seed on the threshing floor. When the contaminated seed is sown, the fungus spores germinate at the same time as the seed of the crop plant and the thin strands of the smut fungus (infection hyphae) penetrate the seedlings and grow within the infected plant unnoticed until ear heads show up with normal seeds, replaced by black powder consisting of smut spores. Because the germina-

Fig. 6
Covered smut of barley—a seedling infected smut.

ting smut spores remain on the outer surface of the seed, these seedling-infecting smuts are most effectively controlled by seed dressings of mercurial fungicides such as Agrosan GN and Ceresan or non-mercurials like Thiram and Captan. The current cost of treatment is Rs. 1.58 per quintal of the cereal in the fungicide seed ratio of 1:320.

The floral-infecting smuts are internally seed-borne and because the infection hyphae enter the ovule during the pollination of flowers and remain lodged inside during the seed formation, the external application of fungicides on the seed surface is of no use. The loose smut of wheat (Fig. 7) and barley are typical examples of floral-infecting smuts. The smutted ears appear before the normal ones and can be rogued out and burnt in order to avoid spread of the disease to healthy plants.

A Danish mycologist devised a method of controlling the loose smut of wheat as follows: the dormant mycelium inside the seed is allowed to germinate by soaking the seed in water for 4 to 5 hours at a temperature of 26°C to 30°C, then quickly transferred for 10 minutes to warmer water kept at the constant temperature of 54°C so that the activated mycelium of the fungus is killed. After treatment, the smut-free seed is dried and stored for sowing. In the plains of Northern India, the summer heat is sufficiently intense for killing the loose smut mycelium hidden inside the wheat embryo. In the Punjab, the hot water technique is modified in order to utilize the solar heat for killing this dormant mycelium. Early in the morning, shallow, flat-bottomed tubs are used to immerse wheat seed, suspected to have been harvested from a loose smut-infected crop. After the seed is soaked in water for about 4 hours enabling the internal mycelium to come closer to the surface of the swollen seed, the tubs are exposed to the hot summer sun for about 5 hours. Then the water is decanted from the tubs and the solar heat-treated seed is spread in thin layers on cow dung, smeared or cemented threshing floors in the afternoon to dry. The sun-dried grain in labelled gunny bags. An almost loose smut-free crop is obtained by sowing

Fig. 7
Loose smut of wheat—a floral infecting smut

Fig. 8
Alternaria blight of wheat

solar heat-treated wheat. Barley seed is given a similar treatment. Systemic fungicides affect the bodily system of a plant as a whole. Two systemic fungicides, D-735-75 W and F 461-75 W, which are oxithin derivatives have lately given encouraging results in the control of floral-infection smuts, e.g., loose smut of wheat in India.

The use of field-resistant varieties offers the best method of controlling loose smut of wheat, and barley and other floral infecting smuts. The advice of the State Departments of Agriculture should be taken for the choice of resistant varieties for general cultivation. Some of the loose smut-resistant wheat varieties recommended for cultivation are: NP. 770, 792, 798, 809 and 824. On hills above 1829 m. or 6,000 ft. NP. 770 is recommended. NP. 710 shows high field resistance to loose smut and black rust.

Alternaria Blight of Wheat : The recent introduction of the high-yielding dwarf Mexican wheats in India has not been a one-sided boon. On December 15, 1966 Dr. C. S. Holton, Plant Pathologist of the U.S. Department of Agriculture, presented an invitation paper before the National Institute of Sciences, India, on "Plant disease pitfalls for high-yielding wheats in India", in which he highlighted Alternaria blight as a new hazard to wheat cultivation in the following statement :

"Alternaria blight, a newly-recognized wheat disease of economic importance in India, presents a major problem to wheat production in several areas, especially in durum wheats. In epidemic proportions the destructive impact of this disease may wipe out an entire crop. According to one report, the Kenphad wheats which were developed as rust-resistant varieties in Maharashtra, failed entirely because of heavy damage from Alternaria blight. If the future high-yielding varieties prove to be susceptible to this disease, it could easily nullify all of their potential for increased production in areas infested with this blight fungus."

The disease first appears in November as small, oval, discoloured lesions, irregularly scattered on the leaves. As the

spots enlarge, they become irregular in shape and dark brown to grey in colour, with pronounced symptoms of blightening. A bright yellow marginal zone appears around the spots which are joined together to cover large areas, resulting in the death of the entire leaf (Fig. 8). Under moist conditions, black powdery fungus spores *Alternaria triticina* cover the leaf lesions (localized spots of tissue). The first signs of the disease appear on the lowermost leaves and gradually spread to the upper leaves. In cases of severe infection, leaf sheaths, ears, glumes and awns are similarly affected and the disease becomes devastating by February.

The Kenphad and Mexican wheats are highly susceptible to Alternaria blight, whereas some American wheats, *e.g.*, H-44, Ceres, Thatcher, Gabo and some NP varieties are field-resistant to Alternaria blight as well as to black rust.

The disease is internally seed-borne. Hot water treatment at 45°C for 10 minutes eliminates the infection in the seed. To prevent secondary infection and spread of the disease, chemical control of Alternaria blight has been attempted with success. According to the conditions of spread, a prophylactic (Gk. *prophulaktikos*, *pro*=before+*phulassein*=to guard) spray and two or three more sprays of dithiocarbamate compounds like Dithane Z-78, Ziram or Cuman are recommended. If conventional sprayers like the Maruti sprayer is used, 3 kg. of 75% zinc dithiocarbamate, *e.g.*, Cuman or Ziram, is dissolved in 800 to 1,000 litres of water and by low volume sprayers only 250 litres of water are required for spraying one hectare of the affected field.

Black Point of Wheat: The 1967-68 season in Northern India was marked by prolonged rains and cloudy weather. It is not unusual under such conditions that wheat ears become mouldy, leaving a black crust of dark coloured fungi on the seed coat. The black point-affected wheat is easily distinguished by a blackish colouration towards the germinal end of the seed. The cultivators are often alarmed lest the black-pointed wheat seed germinate poorly. If the seed moisture in storage is 8 per cent,

Fig. 9
Helminthosporium blight of paddy.

the saprophytic *Alternaria tenuis* is encountered in 80 to 90 per cent of cases. *Helminthosporium* sp. and *Fusarium* sp. are recovered on isolation from about 5 percent samples. These fungi do not in any way affect seed germination. If, however, the seed moisture content is raised to over 13.5 per cent, storage fungi *Aspergillus* and *Penicillium* appear and decompose the seed. The National Seed Corporation, the U. P. Agricultural University and other recognized seed distribution agencies supply only certified seed which is processed and treated with fungicides like Thiram according to International standards. Cultivators should use only certified seed which is safe for sowing.

Diseases of Rice

At least three diseases of rice have assumed national importance in India : Helminthosporium blight, blast and bacterial blight. Helminthosporium blight, was responsible for the Bengal famine in 1943; blast of rice caused damage upto 43 per cent in 1959 in Cuttack and is generally destructive to crops in Andhra Pradesh, Mysore, Kerala, Maharashtra, Orissa and Kashmir; bacterial blight spread like wild fire in Orissa, Bihar and Uttar Pradesh in 1964.

Helminthosporium Blight : This disease is characterized by poor seed germination and dense leaf spotting (Fig. 9). The disease is both soil and seed-borne. Seed disinfection by organo-mercurial compounds like Agrosan GN or Ceresan, destruction of infected stubbles by burning and the use of field-resistant varieties such as T. 498-2A (Bihar), Co. 20 (Madras), BAM. 10 and T. 141 (Orissa) and the Chinese varieties CH. 13 and

(*a*) (*b*) (*c*)

Fig. 5—The three rusts of wheat

(*a*) Black rust (*b*) Brown rust (*c*) Yellow rust

(*see page 15*)

Fig. 10—Blast of rice
(see page 25)

CH. 45 are the recommended control measures.

Blast : Blast or rotten neck of rice is known throughout the world where this crop is grown. Characteristic symptoms of severe leaf spotting and neck rot appear in post-transplanted crops (Fig. 10). It is estimated that each 10 per cent increase in neck rot infection results in an approximately 4.5 per cent increase in loss of yield. The lesions at the neck region also cause the stem to break over. Thus the destruction of the crop may be total and the crop-yield may be only the chaffed earheads. The blast fungus, *Piricularia oryzae*, survives on rice stubbles and some grasses in the rice fields. This accounts for the annual recurrence of the disease. When the relative humidity is above 90 per cent and the atmospheric temperature is 20°C to 24°C, epidemics of blast may break out. Disease forecasts in different rice regions in India can be made on this basis.

Commercial varieties which have been found to escape blast infection in the field are : T. 608 and T. 141 (Orissa), Co. 25, Co. 26 and ATD 25 (Madras) and A. 67, A. 90, A. 200 and A. 249 (Maharashtra). Further enquiries regarding blast-resistant varieties for different tracts in India can be made from the Director, Central Rice Research Institute, Cuttack.

Chemical control minimizes losses from blast. Seedling infection can be prevented by one spray of Ceresan Wet when the seedlings are 21 days old. In order to prevent spread of blast to healthy plants, the crop should be sprayed with copper fungicides, *e.g.*, Blitox-50, Coppesan, etc., at the rate of 5 kg. per hectare or an organo-mercurial fungicide such as Ceresan Wet at the rate of 2 kg. per hectare mixed with 800 to 1000 litres of water when conventional type of sprayers are used. According to the recommendation of the Central Rice Research Institute, Cuttack, the quantity of fungicides can be reduced to one-fifth and mixed with 200 litres of water while using a low-volume power-sprayer. Two or three sprays at 10 days' interval at the tillering stage and one spray at the earhead emergence stage followed by yet another spray at 5 days' interval are advisable.

False Smut or Green Smut: This disease is not caused by a smut but by a sac fungus, *Ustilaginoidea virens*. It rarely causes much damage but in damp weather, the cultivator frequently finds some of the normal grains of rice transformed into velvety-green masses more than twice the size of the normal grain. The life history of the causal organism is not yet understood. Recommended control measures are long rotation of the crop, steepage of seed in water in order to remove false smutted grain and use of disease-free seed.

Bacterial Leaf Blight : With the introduction of high-yielding foreign varieties of rice in India such as Taichung Native 1 and I.R. 8, leaf blight of paddy caused by the bacterium *Xanthomonas oryzae* has become a serious problem in the last few years in almost all the rice-growing tracts of India. Nearly 25 per cent loss in yield is attributed to this disease.

Bacterial leaf blight of rice is characterized by the appearance of greenish-yellow lesions along one or both margins of leaf. These lesions soon coalesce and turn into long, yellowish stripes with brown wavy margins When the disease assumes epidemic form, entire leaves dry up and the whole crop may look as if burnt by fire.

Although an entirely successful method to control this disease has not been found, the disease can be appreciably reduced by sowing chemically pre-treated seed obtained from a disease-free crop. This treatment consists of soaking the seed for 12 hours in a solution of 11.2 gm. Ceresan Wet plus 3 gm. Streptocycline

Fig. 11—Bacterial blight of rice.

in 112 litres of water. Before transplanting, the seedlings should be dipped in 0.5 per cent solution of a copper fungicide, *e.g.*, Blitox-50. The rice crop should then be sprayed with a low-volume sprayer at intervals of 40, 60, 75, 85 and 95 days after transplanting with a mixture of 280 gm. Blitox-50 plus 7.5 gm. Streptocycline in 280 litres of water per hectare.

It is advisable to have the cultivation of Taichung Native-1 during the summer season when the weather conditions are not favourable to the development of bacterial blight. The varieties Tainan-3, Chianung - 242 and IRRI 70/470 are fieldresistant, whereas Taichung 65 is moderately susceptible. Commercial varieties like Taichung Native-1, China-4, Dular, Almora local, NP. 30 and NP. 97 are highly susceptible.

Khaira Disease : Unlike fungoid or bacterial diseases of rice caused by living agents, the khaira disease is now known to be of non-parasitic nature. High soil alkanity and poor zinc availability are the causes of this disease which is most prevalent in two to three-week old transplanted crops in the low-lying *tarai* regions of Uttar Pradesh. Cultivators are often alarmed by the characteristic symptoms of stunting of plants and reddish-brown discolouration of leaves. On uprooting Khaira-affected plants, retarded brown root systems are found. Within about six weeks from transplanting, a few affected plants may recover naturally but the majority of them remain unaffected unless the soil reaction is changed to favour the development of the plant and the nutritional deficiency is corrected by external application of zinc.

Satisfactory control of the Khaira disease is obtained by spraying the crops every 10 days with watery solutions of slaked lime and zinc sulphate. The recommendation is to dissolve 5 kg. zinc sulphate with half the quantity (2.5 kg.) of slaked lime in 250 litres of water if a low-volume sprayer is to be used or in 800 to 1,000 litres of water if the conventional type of sprayer is used.

Diseases of Maize

Maize is the third most important cereal crop after wheat and rice. It is subject to a few important diseases in India. According to USDA (1965), losses in agriculture, maize diseases caused an annual loss of 9.4 per cent of the annual potential production.

Maize Stalk-Rot : Since the introduction of hybrid maize in India, this bacterial disease has caused much damage. The complete rotting of the stalk and leaves noticed in the sub-mountainous areas of Uttar Pradesh is due to *Pseudomonas lapsa*. Another type of stalk-rot occurs at the lower nodes. At times only the rind is involved. Affected stalk tissues become shredded and the plant topples down. The bacterium *Erwinia carotovora* f. sp. *zeae* is responsible for this type of stalk-rot. Some breeding lines under the Inter-Asian Maize Improvement Programme have shown resistance at Pantnagar. Field sanitation, chlorinated water for irrigation, and control of insects by insecticides also reduce the disease.

Leaf Blight : Large grey spots appear on leaves in May and June in the hills and in severe cases the affected leaves become blotched and dry up. The fungus *Helminthosporium turcicum* incites leaf spotting and blight. Losses estimated at the I.A.R.I., New Delhi, varied from 27 to 91 per cent. Primary infection can be prevented by seed dressing before sowing with Agrosan GN or Ceresan at the rate of 1:400 by weight.

Downy Mildew : Caused by *Sclerospora philippenensis*, this disease is recognized by the irregular yellow discolouration on the upper surface with whitish downy growth on the corresponding lower surface of leaves. In advanced cases the leaves are shredded. Preventive sprays with 0.3 per cent Dithane Z-78 are recommended.

CHAPTER IV

DISEASES OF SORGHUM, MILLETS AND PULSES

Sorghum and millet crops serve a double purpose in India. The working class uses the sorghum and millet grain as food and domesticated cattle use stalks and leaves as fodder. These poor man's grain crops can withstand drought and can be grown successfully in poor dry soils of the tropics. The losses in sorghum and millets due to diseases are estimated at 9 per cent in India, sorghum smut alone accounting for a 6.6 per cent loss in grain-yield. Whereas the cereals, sorghum and millets are rich in starch and provide energy for our daily work, protein-rich pulses like soybean, lentil, pea, bean, gram and *Phaseolus* spp. (*mung*, *urid*, etc.) maintain and build our body. As compared to well-developed European countries and the United Stated of America, the yields of these crops are very low in India, partly because intensive plant protection measures are not applied.

Smuts of Sorghum and Millets

As discussed under cereal diseases, all economically important smuts are either seedling or floral-infecting. The seedling-infecting smuts can be satisfactorily controlled by fungicidal seed dressing before sowing, whereas floral-infecting smuts require hot water seed treatment and continuous roguing of smutted ears from the crop.

Seedling-Infecting Smuts of Sorghum and Millets : The grain smut or kernel smut of *jowar* (*Sorghum vulgare*) caused by the fungus *Sphacelotheca sorghi* is a typical seedling-infecting disease which caused the normal grain to be replaced by an oval, dirty-grey sac, measuring 5 to 15 mm. in length and 3 to 5 mm. in breadth. This tough membraned sac is full of black dust consisting of smut spores which can germinate to cause infection even after 13 years. It has been reported that farmers

and labourers handling smutted ears on the threshing floor often suffer from asthma or hay fever caused by the inhalation of spores.

Infection of sorghum smut is externally seed-borne and occurs only in the seedling stage. The life-cycle of the grain smut of *jowar* as represented in Fig. 12 is typical of other seedling-infecting smuts also, such as loose smut of *jowar*, smuts of foxtail millet (*tenai*), finger millet (*ragi* or *madua*), Japanese Barnyard millet (*sawan*) and *kodo* millet.

If the *jowar* seed is sown at a depth of about 4 cm. and the fields are irrigated immediately after sowing, smut infection is reduced but not controlled as effectively as by treating the seeds with fungicides before sowing. The cost of treatment of seed is also very little, about Re. 1.58 per quintal of seed, *i.e.*, 313 gm. of the fungicide per quintal of seed in the proportion of 1: 320. The current prices of the seed-dressing fungicides Agrosan GN., Hexasan (1% Mercury), Ceresan Dry and Tillex are Rs. 4. 34 per kg.

Floral-Infecting Smuts of Sorghum and Millets : In this category of smuts with a typical life-cycle shown diagrammatically in Fig. 13, only two smuts are important in India—the long smut of *jowar* and the smut of pearl millet or *bajra* smut.

In the long smut of *jowar* about 15 per cent grains of the earhead are affected and can be recognized by their size (4 cm. in length and 6 to 8 mm. in breadth) and a yellow membranous covering. This smut is prevalent in the States of Andhra Pradesh, Madras, Madhya Pradesh, Maharashtra, Mysore and Uttar Pradesh. Since the infection is air-borne and through the flower, no satisfactory control has been evolved. It has, however, been observed that early sowing reduces long smut incidence.

The smut of *bajra* is prevalent where this millet is grown in India. Isolated affected grains measure 3 to 4 mm. × 2 to 3 mm. and their colour varies from bright green to brown or dirty black at maturity. In Andhra Pradesh and Madras up to 30 per cent infected plants have been observed. Infection

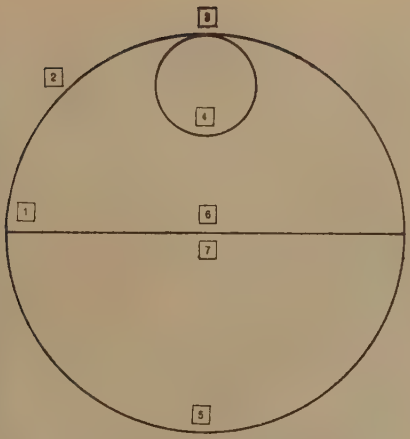

Fig. 12—Life cycle of a seedling-effecting smut

1. Seedling infection 2. Systemic 3. Smutted ears 4. Secondary 5. Spores on seed and soil 6. In season 7. Out of season

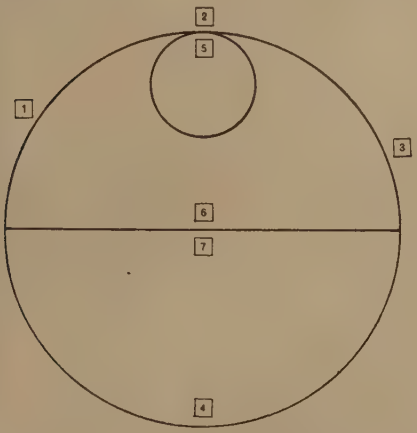

Fig. 13—Life cycle of a floral-infecting smut

1. Air borne spores 2. Floral infection 3. Smut-spore powder in ears 4. Spore balls in soil 5. Secondary infection 6. In season 7. Off season

borne, chemical control is difficult. During drier seasons, late-flowering varieties are known to escape infection.

Bajra Green Ear, Ergot and Rust

These three diseases are conspicuous on bajra and are serious enough in some years in different parts of India.

The green ear of *bajra* is caused by the downy mildew fungus *Sclerospora graminicola*. Although the first symptoms of infection by this fungus appear on very young plants with loss of green colour of the leaves, the transformation of the earhead, wholly or partly, into a green head of small, twisted leaf-like structures is characteristic of the disease (Fig. 14); hence the name "green ear". The shredded brown leaves contain thousands of thick-walled spores of the fungus and help in the survival of the pathogen and the recurrence of the disease. Because the disease is soil-borne, fungicidal seed-dressings before sowing are not effective in controlling this disease. An improved strain of *bajra* named K. 1 from Madras has shown high field-resistance to green ear.

The ergot of *bajra* (Fig 15) caused by *Claviceps microcephala* kno vn for serious losses in Gold Coast, Gambia, Tanganyika and other African countries is now causing concern in India also. Pinkish, honey-like liquid or honeydew exudes from small flower clusters called spikelets and in later

Fig. 15—Ergot of bajra

Fig. 14—Green ear disease of bajra

(see page 32)

Fig. 17—Early blight of potato

(see page 38)

stages of the disease, small, dark-brown sclerotia project between the glumes Thus seed-setting may be completely inhibited. Hybrid bajra varities recently released for general cultivation in India are highly susceptible. Awned varieties of bajra usually escape infection. Chances of secondary spread of the disease can be reduced by spraying the crop with 0.2 per cent Zineb during the flowering stage. Ergot sclerotia are lighter than the healthy seed and can be separated by floatation in 2 per cent saline water. Skimmed sclerotia should be destroyed by burning. To avoid saline injury, the sedimented seed should be washed several times in water before sowing.

Diseases of Pulses

Pulse crops often show symptoms of such diseases as leaf mosaic, root rot, wilt, anthracnose (ulcer-like areas), die-back death of branches at the tips and moving backwards), blights (severe leaf-spotting and death of stems, leaves, flowers, etc.) and powdery and downy mildews (white or creamy powder on upper surface of leaves is a symptom of powdery mildew and downy felt-like growth on the under surface of leaves is characteristic of downy mildews). Losses due to disease in pulse crops are appreciable, though accurate estimates are not available in India.

Fusarium Wilts : Wilts caused by *Fusarium* spp. affect pulse crops in varying degrees due to the toxins of these fungi interfering with the utilization of water by the plant. Among the wilts of legume or pulse crops, the wilt of *arhar* (*Cajanus cajan*) is the most serious and has attracted the attention of plant pathologists in India for several decades. Sudden withering and drying up of green parts either partially or wholly with characteristic black streaks on stems are observed from May to December in North Indian plains and Peninsular India. Sometimes the characteristic black bands are traceable up to a height of several feet from the ground. The fungus survives in the soil and stubbles for long periods. So there is no direct

or chemical treatment for its control. mixed cropping with *jowar* reduces the disease. But mixed cropping not being a scientific practice, the best method is to use locally recommended field-resistant *arhar* varieties such as ST 1, ST 2 and ST 3 (Andhra Pradesh), type 17 (Uttar Pradesh). NP 80 in also field-resistant.

Stem Canker of Arhar: In Northern India this disease is caused by the fungus *Diplodia cajani*. In Septemper, 1968, an international furore was caused by the alleged introduction of this fungus as a supposedly dangerous pathogen of legume crops in Cuba. The fungus is considered harmless except that in certain undetermined conditions it causes canker lesions up to 5 cm. girdling the stem in the collar region with consequent break-over of the whole plant. Very little is known about the transmission and perpetuation of the disease. Before the appearance of the disease, prophylactic paining of collar regions with Chaubattia paste (Copper carbonate 4 parts + red lead 4 parts + linseed oil 5 parts) is recommended for minimizing damage.

Bean Anthracnose : The most characteristic symptoms of bean anthracnose are the black, sunken cankers on the pods (Fig. 16). Blackened dead portions may appear on the foliage and sunken lesions on the embryo

Fig. 16 Bean anthracnose

leaves (cotyledons) and stems of the young plants so that with these damaged organs, the plant dies or becomes worthless. Pink masses of fungus spores exude from these lesions in moist weather. Seeds obtained from localities where bean anthracnose-free crops can be grown should only be used for sowing but where susceptible seed beans must be grown, it is recommended that only fungicidal-dressed seed (1 part fungicide, *e.g.*, Agrosan GN or Ceresan and 400 parts seed) should be sown and the crop should be given 2 to 3 weekly sprayings with 0.2 per cent Ziram with a spreader material like Albolineum.

Pea Rust and Mildews : In suitable weather sometimes these diseases become conspicuous on pea crops in North Indian plains and hill regions of India.

Rust appear from January to March in the form of yellow pustules (Lat. *pustula* = blister), later turning dark brown and full of rust dust (spores) which infect new healthy crops in the neighbourhood. Usually one dusting with 300 mesh sulphur at the rate of 22 to 25 kg. per hectare or Thiovit (0.1—0.3%) is sufficient to control the disease.

The pea crop suffers both from powdery and downy mildews. By the end of January and February when the pea plants are in the pod stage and the weather is dry, the powdery mildew fungus *Erysiphe polygoni* may rapidly spread over the foliage and give an appearance of being covered with a talc-like powder. Estimated losses at New Delhi varied from 9 to 47 per cent. One should be able to recognize powdery mildew in its earliest symptoms when small, circular, powdery spots appear on the upper surface of the older leaves. At this stage of the disease, if the plants are dusted once with 300 mesh sulphur at the rate of 22 to 25 kg. per hectare or sprayed with 800 to 1000 litres of 0.2—0.3 per cent wettable sulphur like Thiovit or with 0.2 to 0.3 per cent Karathane per hectare, this treatment will give perfect control.

In contrast to powdery mildew favoured by dry weather, the downy mildew is a typically moist weather disease which can be controlled by chemical sprays. The first sign of the

disease is the white downy fruiting of the fungus (*Peronospora pisi*) which may in old age appear in shades of violet or almost black. Seed treatment in hot water at 122°F (50°C) for 25 minutes controls initial infection and spraying the crop with 0.2 per cent Zineb or Maneb control secondary spread of the disease. Destruction of debris of the affected crops is also recommended. This disease is prevalent in Northern India in moist cool weather.

Gram Blight and Wilt : A serious blight of gram caused by the fungus *Mycosphaerella rabiei* has often caused losses up to 50 per cent of the crop in the Punjab from February to April. The fungus attacks all the above-ground parts of the plant with characteristic circular lesions and scorched brown appearance of the leaves. The causal organism is both externally and internally seed-borne and, therefore, the only method of control is to use resistant varieties of gram in general cultivation recommended by the State Agriculture Departments and to destroy the debris of the affected plants by burning.

The wilt of gram may be due to a soil-borne fungus, *Fusarium orthoceras* var. *ciceri* or due to physiologic, non-living causes or to both causes in the North Indian plains. The affected plants first turn yellow, then dry up gradually. The fungus attacks the root system resulting in the blackening and death of the wilted plant. If plants wilt at the time of flowering or fruiting, either no seeds are formed or only shrivelled seeds are obtained. Since the disease is soil-borne, there is no effective chemical control. Late-sown crops are less affected by wilt. Efforts are being made to evolve field-resistant varieties.

CHAPTER V

DISEASES OF POTATO

POTATO is the tastiest, carbohydrate-rich, energizing food preferred by man and also by numerous pathogenic fungi, bacteria, viruses and nematodes. Unlike cereals which are grown from true seed, potato is a vegetatively propagated crop. Potato tubers which are modified underground stems are used as seed. It is generally recognized that vegetatively propagated crops are subject to a larger of number diseases as compared to crops raised from true seed. During the many years that potato has been cultivated, large numbers of diseases have caused losses, some of them so serious that national economies of countries have sometimes been upset and even governments overthrown such as the Irish government during the 1845 potato blight epidemic. On a world basis, the total loss due to diseases corresponds to 32.3 per cent of the actual crop production.

In India, potato seems to have been introduced by the Portuguese during Jahangir's reign. In Uttar Pradesh it was introduced by Major Young in the Dehra Dun valley about the same time. Potato was then a delicacy for the Moghul king, today it is included in the daily diet of the poorest in India. During 1965-66, 473.2 thousand hectares were under potato cultivation, producing 3,893.1 thousand metric tonnes of tubers in India.

Though potato is a vegetable, the complex of potato diseases is regarded as a separate study. Some of the major diseases of potato in India are discussed here.

FUNGOID DISEASES

Potato Blight : The early and late blights of potato are still the most serious diseases in India, causing over 15 per cent losses to crops in certain years.

The early blight is recognized by the appearance of pale-

brown spots on the tips and margins of potato leaves which later on develop into large concentric, brown rings (Fig. 17). The characteristic concentric rings are formed by the pathogen *Alternaria solani* by its vegetative growth during the day when it is warm and sporulation at night when it is cool. In moist weather this disease is quite prevalent in the States of Assam, Bihar, Himachal Pradesh, Mysore, the Punjab, Tripura, West Bengal, North Himalayan regions and the Gangetic plain of Uttar Pradesh.

The late blight of potato, which appears later in the season, is characterized by brown patches appearing and enlarging on the leaves (Fig. 18). The stems of the potato plant may also be affected, crumbling down the whole plant. Potato tubers from the affected crop show discolouration (Fig. 19) and rot in storage. If such seed is sown, the disease is reproduced in a serious form. Occasional late blight epidemics in the plains of India have also been reported due to the use of seed obtained from blight-infected crops in the hills and kept in cold storage in the plains. Sometimes late blight in the plains is also caused by another fungus *Phytophthora himalayensis* which can tolerate high temperatures.

It is now a universal practice with potato cultivators frequently to spray their crops before and after the advent of these diseases with copper fungicides (Cupravit, Blitox-50, Fycol 8E etc.) or dithiocarbamate compounds (Dithane Z-78). Earlier records in India show that spraying Bordeaux mixture (4:4:50)[1] at high altitudes resulted in a yield increase of 32

[1] Method of preparing fresh Bordeaux mixture (4:4:50) : 4 lbs. Copper sulphate+4 lbs. quick lime+50 gallons water is 0.8 per cent Bordeaux mixture which can be prepared by suspending overnight 1 kg. Copper sulphate tied in a gunny cloth in 30 litres of water contained in a wooden or copper vessel; 1 kg. of quick lime is dissolved in 15 litres of water (preferably hot water) in an earthen vessel separately in the morning. This lime is poured into the copper sulphate solution through a strainer and the mixture is made up to 125 litres. This solution should be neutral and, therefore, it is tested before using by

(Contd on page 39)

per cent in 1948 when the incidence of potato late blight was slight, and 77 per cent in 1949 which was a severe blight year. Generally blight losses in the plains are lower though sometimes in seasons like 1950-51, nearly 10 to 65 per cent crop was lost. In addition to Bordeaux mixture (4:4:50), 0.2 per-cent Dithane Z-78 or Dithane M-22 as dithiocarbamate compounds or 0.4 per cent copper compounds such as Kirti Copper or Copper Sandoz or 0.2 per cent oil-based Copper compound Fycol 8E are equally effective in controlling both early and late blights of potato in the plains. In recent years, potato-growers in America have changed over from copper fungicides such as Bordeaux mixture, copper oxychlorides and cuprous oxides to new organic fungicides of the dithiocarbamate series, *e.g.*, Dithane Z-78 and Dithane M-22 or to Captan compound because spraying the potato crop not only prevents fungal attack but also increases potato yields substantially. Recent experiments conducted at Jorhat, Assam, have shown the superiority of Dithane M-45 over Blitox and Captan in controlling potato late blight.

There is no doubt that late blight is a catastrophic disease sometimes but unrealistic fear of blight epidemics is uncalled for as stated by two well-known FAO authorities, Drs. Vallega and Chiarappa in 1964 :

"Potato blight, caused by *Phytophthora infestans* (Mont.) de By., is often cited as causing serious losses. However, this is not always true. In fact, from recent realistic estimates of blight losses, it now appears that actual yields of potatoes are often the highest in blight years, despite losses due to this

immersing a shining knife blade or some iron strip for a few minutes and if there is any copper deposition on it, requisite quantity of lime is added until there is no copper deposition. Similarly, neutrality of Bordeaux mixture can also be tested more accurately by "Merck's universal indicator paper".

Bordeaux mixture, which has to be prepared fresh before use, causes russeting of fruit, severe infection to leaves and premature defoliation. Since 1930, many new commercial fungicides are being used such as Copper organic combinations and dithiocarbamates.

disease. During such years, abundant rain favours plant development and increased tuber formation. On the other hand, in years of little or no rain, blight is checked but plants suffer from drought. From a world-wide study of blight epidemics by Cox and Large (1960), it would appear that this conclusion applies to most of the potato-growing areas of the world. This should not mean, however, that blight epidemics have not been or cannot occasionally be catastrophic in nature, for even in present days blight may cause distress and privation."

Fig. 20
Potato Wart

Potato Wart : Diseases introduced from foreign countries often cause tremendous losses. One such disease known as potato wart, characterized by the development of greenish-yellow warts of variable size, mostly on the tubers (Fig. 20) was accidentally introduced in 1953 in a small plot, about one-tenth of an acre in Darjeeling, on an imported variety of seed potatoes. Immediate steps were taken for its complete eradication and to prevent its spread in any new area. But in spite of all precautions, the disease seems to have spread to the whole of West

Bengal and possibly to Assam. Cultivators are advised not to import seed potato from these Indian States and also from European countries like Hungary where this disease was first reported in 1896. However, disease free potato seed certified by a competent authority can be used.

Greenish-yellow warts later on darken in colour and the diseased potatoes eventually decay. The fungus produces numerous thin-walled sacs in the host tissues from which motile gametes are liberated. These gametes fuse in pairs and thick-walled, resting, brownish-black, tiny balls about 0.05 mm. are formed. As the warts decay, these resting balls (sporangia) mix up in soil only to germinate and infect young tubers after a period of rest. The fungus is known to survive in the soil from 8 to 12 years; therefore, crop rotations are not effective in checking the disease. Soil treatment with fungicides is also of no use and there are no resistant varieties which can be recommended to the Indian cultivator.

With a view to preventing the entry of serious pests and diseases of potato like Colorado beetle, Wart and Golden nematode, the Government of India framed the following rules:

"Potatoes, other than potatoes from Burma, shall not be imported into India by sea, except through the port of Bombay or Madras, unless such potatoes are inspected and, if necessary, fumigated and disinfected by the Plant Protection Adviser to the Government of India or any person duly empowered by him on his behalf at the port of Bombay or Madras and certified by him to be free from pests and diseases and are also accompanied by—

(*a*) a certificate from the consignor stating fully in what country and in what district of such country the potatoes were grown, and

(*b*) an official certificate stating—

(i) that no case of wart disease (*Synchytrium endobioticum*) of potatoes or the existence of the pests, Golden nematode (*Heterodera rostochiensis*) and Colorado potato beetle (*Leptinotarsa decemlineata*) in any stage of development has occurred

at any time during twelve months preceding the date of the certificate within five miles of the place where the potatoes included in the consignment were grown;

(ii) that the crop from which the potatoes were derived was officially inspected in the field and that the degree of freedom from virus diseases was sufficiently high to ensure the suitability of the progeny for seed purposes and that the said crop was not grown in the vicinity of any unhealthy potato crop;

(iii) that a representative sample of potatoes included in the consignment was thoroughly examined and found to be healthy and there was no evidence in it of the presence of any insect pest or fungus destructive to agricultural and horticultural crops;

(iv) that the potatoes included in the consignment are free from Colorado beetle, Golden nematode and wart disease.

Provided also that potatoes may be imported under a certificate from the Head of Division of Botany, Indian Agricultural Research Institute, or the Plant Protection Adviser to the Government of India, or the Director, Central Potato Research Institute".

Black Scurf : This disease occurs wherever potatoes are grown. Cultivators are familiar with this disease as the "dirt that will not wash off". The "dirt" consists of fine threads and small, bare mycelial knots of the fungus *Rhizoctonia solani* which can cause dark-brown lesions on the stems, young tubers and roots of the potato plant. The leaves of the diseased plant are often rich green to begin with and yellowish later on. Control of this disease is difficult because the fungus is soil-borne and very resistant to adverse conditions. Long rotation of at least three years and seed treatment with corrosive sublimate solution under supervision of a specialist are recommended.

Bacterial Brown Rot of Potato

This is the most serious disease in the mid-hilly regions of the Almora, Dehra Dun, Garhwal and Nainital districts of

Uttar Pradesh. The bacterium *Pseudomonas solanacearum* survives in the soil and infected potatoes and appears almost every year on potato crops in these areas. It has also been reported to cause damage in the Nilgiri Hills and the plateau regions of Maharashtra and Mysore. The characteristic symptoms are those of general wilting and distinct brown rot rings with bacteria oozing out in drops on the surface of cut potato obtained immediately after harvest (Fig. 21). The bacterial pathogen also affects many kinds of plants of Solanaceae family to which potato also belongs. The disease is spread by soil, irrigation water, infected potato tubers and other susceptible plants. During 1951-55, studies on this disease by the scientists of the Central Potato Research Institute (C.P.R.I.) at Bhowali, district Nainital, have led to the following recommendations for control :

(1) Use only healthy tubers for sowing, uncontaminated by brown rot-affected potato plant or tubers. Strict disinfection of tools, baskets, etc., and other sanitary measure like burning the affected crop, etc., are necessary while handling seed potato.

Fig. 21.
Bacterial brown rot of potato.

(ii) Three applications of sulphur in the season in the planted rows at the rate of 907 kg. each (total 2721 kg.) of sulphur per hectare.

(iii) Tuber dip or soil treatment with 1.5 to 2.5 per cent of Dithane D-14(Nabam).

(iv) Crop rotation in order to give at least a two years' gap in potato cultivation on the same field and green manuring with sannhemp. The crop rotation which

reduced the disease appreciably was : Potato—Wheat—Green manure with sannhemp—Wheat—Green manure—Potato.

Virus Diseases of Potato

There are numerous viruses which occur all over the world and damage the potato crop. In India at least two virus diseases (mosaic and leaf roll) are known to reduce crop yields by 50 per cent. The mosaic of potato causes stunting of plants with pronounced symptoms of yellow mottling and crinkling of leaves. Leaf roll causes upward cupping and rolling of leaflets (Fig. 22). The upward rolling parallel to the leaf midrib is specially noticeable in the older leaves. The tubers obtained from crops affected by these viruses are very small in size and the yield per plant is consequently also low.

Since mosaic and leaf roll reduce the size of the tubers, it follows that bigger-sized potatoes will give a comparatively mosaic-free crop. Table 2 shows the effect of seed size on the incidence of mosaic.

The data show that mosaic-and leaf roll-affected seed potatoes give a higher percentage of diseased plants as compared to crops raised from large-sized seed which not only give higher yields per hectare but also produce big potatoes. A potato grader is, therefore, useful both for commercial purposes and for obtaining relatively mosaic-free seed. However, the use of virus-free certified seed cannot be minimised.

Because mosaic and leaf roll viruses affect every cell of the plant, they cannot be controlled by chemical applications. The use of virus-free certified seed is, therefore, the only method which is universally adopted for preventing losses from virus diseases. Certified seed is obtained in the following manner:

Aphids spread many viruses of potato, hence it is useless to grow healthy potato near aphid-infested and virus-affected potato fields. Potato crops for seed multiplication and certification are grown in mountain valleys at higher altitudes far away from commercial crops. From such isolated potato

TABLE 2

Showing the effect of seed size on the incidence of mosaic and leaf roll.

Seed size (diameter in inches)	Percentage of infected plants during 1954-55				1955-56			
	Healthy seed		Leaf roll & Mosaic affected seed		Healthy seed		Mosaic & leaf roll affected seed	
	Infection carried through seed	Secondary infection	Infection carried through seed	Secondary infection	Infection carried through seed	Secondary infection	Infection carried through seed	Secondary infection
1.5	16.2	18.4	71.2	74.1	6.9	11.9	38.5	54.3
1.0	18.8	20.2	77.8	80.8	7.4	13.4	49.8	64.8
0.5	21.1	22.8	88.6	90.3	11.8	18.8	60.8	70.9

Fig. 22
Potato leaf roll, a virus disease.

fields a large number of healthy potato plants are carefully selected and tested for purity of variety, freedom from mosaic, leaf roll and other viruses and yield of tubers per plant. Each tuber is then sown separately in small plots and the virus-infected plants are continuously rogued out and destroyed as soon as they show up in the field. This is known as the "tuber indexing method" which helps us to select the nucleus seed stock from the plants left over in the field after roguing the diseased ones. This nucleus seed stock is subsequently used to produce disease-free foundation stocks by rigorously removing the virus-affected plants at least twice during the growing season. Raising seed stocks in hill areas can hardly meet about 20 per cent of the total seed requirements of the country. In order to meet the requirements of certified seed for commercial potato crops in the plains the "seed plot technique" is recommended by the Central Potato Research Institute, Simla.

The seed plot technique consists of utilizing the foundation stock produced in the hills for raising potato crops in the plains in periods of low aphid infestation in potato fields. When potato tubers are fairly well formed, irrigation is restricted or withheld so that the haulms may dry up before the aphid population gets a chance to build up in the plains. According to international standards of purity of seed, the potato tubers are now free from viruses and can be used for more multiplication plots which can supply certified seed potato to commercial growers.

Golden Nematode of Potato

A truly dangerous immigrant to India is the golden nematode *Heterodera rostochiensis*, which was found infecting potato fields in the Nilgiri Hills and New Delhi's Indian Agricultural Research Institute (I.A.R.I.) in recent years.

The immature swollen females and brown cysts (Gk. *kustis*= bladder) of the golden nematode are barely visible to the naked eye (Fig. 23). The cysts are filled with living eggs of the parasite which may hatch and liberate enormous numbers

Fig. 23

Golden nematode—an eelworm parasite of potato

of tiny, snake-like eelworms in the potato fields even after surviving for 10 years. Even if the soil moisture is sufficient, a nematode-infested crop gives the appearance of being starved from fertilizers and water. Potato-yield increases of 25 to 50 per cent have been observed if the nematode-infested fields were fumigated at the proper time by nematicides like Nemagon, but these chemical methods are expensive in the long

Fig. 18—Late blight on a potato leaf

(see page 39)

Fig. 25—Yellow vein mosaic of *bhindi*

(*see page 54*)

run. The precautions to prevent spread of the golden nematode in other parts of India have already been discussed under potato wart.

Blackheart Of Potato

The appearance of this disease in stored potato depends on the conditions of storage and ventilation. Externally the potato tubers may appear perfectly normal but when they are cut into two halves they may show browning or blackening of the interior (Fig. 24). The blackened tissues may be invaded by bacteria which ultimately rot the potatoes giving a foul smell. Then the losses are heavy.

Fig. 24
Blackheart of potato, a non-parasitic disease

Blackheart is a non-parasitic physiologic disease caused by the exclusion of air from potatoes and by high temperatures obtained in storage by deep piling. They should not be stored in deep bins or in continuous high piles of sacks. If they are to be stored for more than six months, they should not be piled more than six feet high even though the temperature of the cold storage does not exceed 45°F or 7.2°C. Potatoes should not be left for a long time in hot sun after digging. In order to increase storage capacity within the same floor space, spaces may be provided between false floors and walls and the storage bins. Even if good ventilation has been provided, the temperature of the storage room should be lower than 60°F (15.6° C) but never above 95°F (35° C).

CHAPTER VI

DISEASES OF VEGETABLES

IN OUR DAILY dietary requirements we need carbohydrates for energy and proteins for building and maintaining our body. But without vegetables and fruits, our diets would lack in vitamins and minerals which are so necessary for ensuring good health.

The literature dealing with vegetable diseases and their control is so vast that nearly 40,000 publications in many languages are available. It is not possible even to give the briefest summary of this literature but we shall give here the diagnostic symptoms of some major diseases that often make vegetable-growing in India very uneconomical. There are a few diseases with similar symptoms such as seedling damping off, nematode root knots, Fusarium wilts and storage rots which cause serious losses in a variety of vegetable crops, whereas there are others which are specific to certain crops only.

GENERAL DISEASES

Seed Rot and Damping off: Vegetable seeds, especially the large ones like bean and okra (*bhindi*) that may often be cracked so that when these are sown, a number of soil organisms invade them and cause seed rot or pre- and post-emergence injuries. This often results in poor stands in the field and if the vegetable-grower does not take precautions to prevent such damage, he is likely to lose time and money in replanting the gaps in the field. Late-sown crops get more disease and are not so remunerative. Therefore progressive growers always overplant and treat vegetable seed with Agrosan GN. or Captan before sowing. If seedlings are to be transplanted, the seed beds should be prepared on raised ground and should have good drainage. The surface soil of seed beds should be sterilized with Formalin and crowding of seedlings and excess

moisture should be avoided. Drenching of seed beds with 0.1% Captan or with freshly prepared Cheshunt compound[1] is also recommended. Seedlings should also be sprayed with 0.3 per cent Blitox-50 or 0.2 per cent Ziram at frequent intervals. The sprays should begin as soon as the first leaves are formed and should be repeated every week as long as damping off is likely to affect the seedlings. These recommendations are applicable for treating seeds and seedlings of bean, beet, cabbage, carrot, cauliflower, sweet corn, lettuce, cucumber, okra, onion, peas, pepper, pumpkin, radish, soybean, spinach, etc. When fungi are found under the seed coat such as *Alternaria* spp. under the seed coats of tomato, cabbage and cauliflower, fungicidal seed-dressing is not effective and such seed should be treated with hot water at 122°F (50° C) for 25 minutes. Water in a metal container with a wooden-slatted bottom can be heated by an oil stove and while the heat is regulated at one end of the container by a thermometer, vegetable seed in half-full cheesebags can be placed at the other end for 25 minutes at a uniform temperature of 122°F (50° C). Small growers and kitchen gardeners will find this a useful device for treating small quantities of vegetable seed.

Root and Foot Rot: Such rots are commonly found in peas, beans, tomato, brinjal and *bhindi* (okra). The disease organisms are seed-borne or soil-borne. Chief symptoms are seedlings rots and sudden drying up of grown up plants. Near the base of the stem, dark brown markings are visible and lower leaves wither. Heavy rains during the early stages of growth of plants followed by high temperature are favourable for the disease. Seed treatment with fungicides and crop rotation with cereals are recommended.

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[1] Cheshunt compound: 2 oz. (56.7 gms.) of finely powdered copper sulphate is mixed thoroughly with 11 oz. (311.8 gms) of ammonium carbonate and left for one day in a tightly stoppered glass bottle; 1 oz. (28.3 gms.) of the compound is dissolved in 2 gallons (8.9 litres) of water; 1 gallon (4.45 litres) of the solution is sufficient for 2 square feet (0.6 square metre) of the bed.

Fusarium Wilts: Fusarium wilts are most important on tomatoes, pea and cucurbits. The chief attack of *Fusarium* spp. is below ground, starting from the finest feeding root and continuing into the tap root. The affected plants may be found from the seedling stage to full maturity and can be recognized in the field by the sudden loss of green lusture and progressive yellowing and drooping and curling of leaves from top downwards and wilting of plants. Sometimes the brown and curled leaves of the wilting plant fall to the ground, leaving the stems bare. There is darkening of the roots and water-conducting vessels within the stem of the wilted plant. Wilting is caused by the production of toxins (Lat. *toxicum*=poison) by the fungus *Fusarium.*

Sometimes other fungi appear on the *Fusarium* infested-root system and decompose it completely. *Fusarium* rarely produces spores while the wilting plant is green but as soon as the host dies, there is abundant sporulation which can be seen by the naked eye as white or pink powder or slime on dry branches. The fungus requires little soil moisture to establish infection. Once it invades the host through feeding roots, it can grow on drier soils over a wide range of temperatures, 42°F to 106°F (5.5°C to 41.1°C). In commercial fields soil-drenching with fungicides is not practicable, hence the use of field-resistant varieties is recommended in consultation with State Departments of Agriculture. In the U.S.A. some sources of resistance have been discovered, *e.g.* P.E.I. 79532 from Peru and other collections of *Lycopersicum pimpinellifolium.* Some of the wilt-resistant varieties of tomato evolved in the U.S.A. are Pan America, Sunray, Fortune and Golden Sphere.

Root Knot of Vegetables : The root knot nematodes, *Meloidogyne javanica, M. incognita* and *M. arenaria* commonly attack tomato, potato. brinjal, chillies, okra (*bhindi*), carrot, radish, colocasia and various cucurbit vegetables. The symptoms of yellowish green drooping leaves and stunted growth of the affected plants are more pronounced in tomatoes than in other crops. On pulling out the root system of the suspected plants,

the presence of large galls of various sizes and shapes on the tap root and lateral roots is characteristic of the root knot disease. Aerial symptoms, not so pronounced as in tomato, can be seen in other vegetable crops but the formation of root knot galls is equally characteristic in all cases.

Flooding of the soil, soil amendment with non-edible oil cakes, *e.g.*, *neem* or *karanj* cake at the rate of 25 quintals per hectare or with saw dust at the same rate of application along with normal doses of NPK fertilizers, or application of 1 gallon Nemagon per acre are known control measures which reduce root knot infestation in vegetable crops.

Special Vegetable Diseases

Phomopsis Blight of Eggplant: The fungus *Phomopsis vexans* is responsible for the damping off of seedlings, leaf blight, stem canker and fruit rot. Irregular grey to brown spots with a light coloured centre are formed in the initial stages of the disease. Later on the affected leaves become yellow and die. A grey dry rot is caused at the base of the stem and pale sunken areas with numerous black flask-like tiny bodies containing hundreds of spores cover the whole fruit. The fruit is thus transformed into a black mummy. The parasitic fungus survives from season to season as dormant mycelium inside the seed and the spores infest the soil, debris and seed.

This is a difficult disease to control. But the following recommendations would help to reduce the disease· Hot water treatment of the seed at 50°C for 30 minutes and light seed dressing with Thiram before sowing; spraying seed-bed and brinjal fields with Captan, Ziram or Dithane M-22 at the rate of 2 kg. in 1000 litres per hectare at weekly intervals; at least three years' rotation and destruction of debris and diseased fruits by burning.

Little Leaf of Brinjal : In almost every State of India, one often comes across bushy, stunted brinjal plants with a few green flowers and scarce fruits. The internodes are shortened and there are bunches of very small leaves. This is a virus disease,

spread in nature by the leaf hoppers, *Eutettix phycitis* and *Empoasca devastans* which also infect tomato, tobacco, potato and other Solanaceous vegetables and weeds. If the infected plants are rogued out in the early stages of the disease and the remaining healthy plants are sprayed with the insecticide Diazinon or Parathion with a mixture of 0.1 per cent BHC and DDT in equal proportions, this disease can be moderately controlled.

Yellow Vein Mosaic of Bhindi (*Okra*) *:* Wherever *bhindi* (*Abelmoschus esculentus*) is grown as a vegetable in India, this virus disease is a serious problem. The diseased plants are conspicuous by the vein-clearing, yellow network of veins of leaves (Fig. 25) and the yellowish green colour of dwarfed and malformed fruits. In nature it is transmitted by the white fly, *Bemisia tabaci*, and several road-side weeds are also infected. Spraying every 10 days with 0.01 per cent Folidol or with 0.03 to 0.04 per cent Parathion or Diazinon, observance of a closed season at least for two months during summer between two successive seasons of okra crop and growing the mosaic-tolerant Pusa Sawani variety are the recommended measures of control. Several species of *Abelmoschus* and *Hibicus* are immune to this disease. These can be used for breeding resistant varieties.

Early Blight of Tomato : The fungus *Alternaria solani* which causes the early blight of potato also causes the early blight of tomato, forming concentrically ringed, circular brown rings on the leaves and fruit and suggesting the appearance of "target spot". It can also cause damping off and collar rot of seedlings. Tomato seed should be treated with hot water at 50°C for 25 minutes and the crop of tomato raised from the treated seed should be sprayed with 2 to 3 kg. Captan, Ziram or Maneb dissolved in 1000 litres per hectare at 10 days' interval.

Tomato Leaf Curl and Big Bud : These two virus diseases are a menace to the tomato crop in India.

When tomatoes suffer from leaf curl, the leaflets are deformed with their margins curled inwards and outwards. The

infected plant is stunted with smaller internodes and bushy growth of leaves. This disease is also spread by the white fly *Bemisia tabaci*. The disease can be kept under check by spraying the crop for three months at 10 days' intervals with 0.04 per cent Parathion.

The big bud disease is manifested first on growing shoots with buds pointed in a vertical direction, calyx segments united upto the tips with bladder-like swellings and toothed opening at the top. These swollen bladder-like buds appear on the sides also and have a purple colouring particularly along the veins. This disease is not yet fully investigated in India.

Blight of Colocasia and Yam : This disease is recognized in the field by the appearance of dark, circular or oval spots in August and September which cover almost the entire surface of the leaves if the rainfall is excessive. Apart from much loss of leaf tissue, the floral spadix and corms may also rot completely due to the attack of the fungi, *Phytophthora colocasiae* and *Colletotrichum* sp. The life-cycle of these pathogens is not yet well understood. Probably the disease is carried through the corms which should be selected disease-free for new planting and the spread of the disease prevented by spraying with Bordeaux mixture (2:2:50) with rosin as a sticker or with 0.2 per cent Zineb (Dithane Z-78), once in July and later at fortnightly intervals, depending upon the severity of the disease. Colocasia variety *Poonam Pat* from Madras is immune, *Sakin V* from Ranchi is resistant and the following varieties are reported to be moderately resistant: *Ahina*, *Bhadia*, *Mukhia kachu* and *Nag kachu* (Assam), Pusa (Bihar), Sakin II (Ranchi) and Simla (Himachal Pradesh).

Powdery Mildew of Cucurbits : A talcum-like growth appears on the foliage and young stems of almost all the cucurbitaceous vegetables in India during cool atmospheric temperature and low humidity (Fig. 26). This growth belongs to the fungus *Erysiphe cichoracearum*, which can be easily controlled by dusting 300 mesh, fine sulphur at the rate of 18 to 20 kg. per hectare or by spraying wettable sulphur such

as 0.2 per cent Thiovit or Karathane at the rate of 800 to 1000 litres per hectare with the conventional type of sprayers. To prevent plant injury, the use of sulphur should be avoided in hot sun.

Die-Back and Fruit Rot of Chillies : The die-back disease in chillies is characterized by the shedding of leaves and death of twigs from the tip backwards. The fruits of the affected plants become soft and rot as a result of fungal infection by *Colletotrichum capsici.* Spray 5:5:50 (1.0%) Bordeaux mixture or 3 kg. of copper containing fungicide in 1000 litres of water per hectare once early in the season and once after fruit setting.

Spoilage of Vegetables During Marketing and Storage

Vegetables, being tender, are easily bruised and spoilt quickly by a number of fungi and a few soft-rotting bacteria. The vegetable packages receive heavy blows by rough handling during storage, rail or truck loading, transit and delivery to the retailer.

Fusarium Rot : Fusarium rots often cause serious losses during the transit and marketing of vegetables. In soils suitable for growing vegetables, many species of *Fusarium* can be found. Thus most vegetables get contaminated during harvest. *Fusarium* rots are generally found on root crops such as sweet potato, carrot, etc., and also on potatoes, tomatoes, onions, peppers, cucumbers and melons. Often a conspicuous white or pink mouldy growth appears on the decaying tissues. *Fusarium* enters through wounds of insects and mechanical injuries caused by tools during harvest and by rough handling of vegetables in transit and marketing. If the produce is quickly disposed of and does not remain in storage even for two or three days, the losses due to decay can be reduced.

Pythium Rot of Cucurbits : Fruit rot of cucurbits by *Pythium,* another fast-growing and soil-inhabiting fungus, is also one of the most common diseases in India during the summer season. During and after rains, most of the fruits lying on the

soil or hanging near ground level begin to decay and the disease spreads on cucurbit fruits such as that of *torai* (*Luffa aegyptiaca* and *L. acutangula*), *kaddu* (*Lagenaria leucantha*, old name, *Lagenaria vulgaris*), *parwal* (*Trichosanthes dioica*), snakegourd (*Trichosanthes anguina*), *kheera* (*Cucumis sativus*), *karela* or bittergourd (*Momordica indica*) and also other cucurbits. If the cucurbit vines are trained on wire or cord to fruit only on dry soil, much of this damage by *Fusarium* spp. or *Pythium* can be avoided.

Aspergillus Black Mould of Onion : A dark saprophytic fungus *Aspergillus niger* often rots onion bulbs in storage. The rotting begins at the top of the bulb where the leaves dry and are cut and also at the bottom where the roots and scales are cut or bruised. The invaded tissue becomes water soaked and the mould appears between the fleshy onion scales. Often soft rot bacteria also work in association with the fungus and make the fleshy onion bulb quite pulpy. Attention should be given to storage in slatted crates in which the onions should be so piled that air can circulate all along. In order to avoid bruises by overcrowding, the crates should not be full. Storage below 13°C helps to prevent the growth of the fungus or the rotting bacteria.

Tomato Fruit Rot : Fruit rotting of tomatoes during storage by *Fusarium* sp., *Alternaria tenuis* or by the bread mould *Rhizopus nigricans* in quite common. As the first sign of spoilage, water-soaked lesions appear which turn yellow, brown or black as they enlarge, covering the whole surface of the fruit surface. The general precautions necessary for preventing spoilage of tomatoes is to dip them in dilute chemical solutions of chlorine or borax or better in a solution of the antibiotic aureofungin at 100 ppm. for 20 minutes and handle them carefully while picking and crating. Only such tomato varieties should be cultivated whose fruits do not crack.

CHAPTER VII

DISEASES OF FRUITS

FROM the very ancient times, the people of India understood the importance of flowers and fruits. That the devotee Shabari offered the *ber* or jujuba fruits (*Zizyphus mauratiana*) to Lord Rama for her redemption is often quoted from the epic, the *Ramayana*. In the *Bhagwata Gita* also, special significance is attached to leaves, flowers and fruits in Shloka 26 of Chapter IX which is quoted below :

पत्रं पुष्पं फलं तोयं यो मे भक्त्या प्रयच्छति ।
तदहं भक्त्युपहृतम् अश्नामि प्रयतात्मनः ॥

"Any offering of leaf, flower, fruit or water made to Me in devotion by an earnest soul, I lovingly accept."

Seasonal fruits grown throughout the year in India are available both to the rich and to the poor. If fruit orchards are not maintained properly, they are infested with numerous diseases. Between the tree and the retail bin, the fruit packages are roughly handled during storage, transit and marketing. They become bruised and numerous fungi and bacteria infest them to cause serious losses. It is estimated that throughout the world 12.6 per cent of actual value of top fruits (apples, pears, plums, cherries, apricots), dates, figs, bananas and pineapples is lost due to diseases. Corresponding losses to grapes and citrus fruits are 23.4 per cent and 9.5 per cent respectively. Losses to fruit crops in India are of the same order, if not greater.

Some of the well known diseases of fruits are discussed in this chapter.

Apple Diseases : "An apple a day keeps the doctor away" is an old proverb. The production of apples in India is seriously affected by diseases in the orchard and rotting in storage and marketing. The diseases most commonly met with in the orchard are the apple scab, apple black-stem, white root rot and collar rot.

Apple scab caused by the fungus *Venturia inaequalis* becomes apparent when the new leaves open in spring. Scattered, brown or olive green almost circular spots with wavy margins appear on the underside of the leaves and soon spread over to pedicels and fruits. Dwarfed and blistered leaves with marginally dead areas are seen in cases of severe infection. The spots on mature fruits are circular, olive green with a dark velvety coating which become scabby with age and crack (Fig. 27). Thus the appearance and quality of fruit are destroyed. Heavily-infected fruits drop down prematurely.

Fig. 27
Apple scab

These symptoms may also appear in storage in cases of late infection. In this infective stage of the disease innumerable spores of the fungus are formed which cause new infections. The fungus overwinters on old fallen leaves. The disease can be controlled most effectively if the fallen leaves are collected from the ground and burnt and each detailed spray programme is carried out thoroughly and in time. Sometimes fungicidal dusting is preferred to spraying specially where very quick coverage is necessary but in most cases it is used to supplement spraying. *Pre-bloom* sprays keep the young bud and fruit parts protected and should begin after the cluster buds have just opened and the leaves have grown out to abour ¼ inch. Fresh liquid lime sulphur [1] 1:60 is a standard material but other commercial

[1] The formula of concentrated lime-sulphur is quick lime 50 lbs. (22.7 kg)., sulphur 100 lbs. (45.4 kg.) and water 50 gallons (222.8 litres).

(contd. on page 60)

fungicides are preferred now-a-days. These should be used in consultation with the specialist. A mild spray *in bloom* such as wettable sulphur (Thiovit, 0.3%) or a dithiocarbamate (Dithane Z-78, 0.2%) may be given 10 days after the last pre-bloom treatment. A few *after-bloom* sprays with the same chemicals should begin at the calyx stage to keep the fruit protected until harvest. In consultation with an insect specialist (entomologist) spray dates are also fixed to control simultaneously the insects as well as the apple scab fungus. Sprays of Thiodon (5 c.c. per gallon) mixed with 0.3% Lonacol controls woolly aphis and apple scab.

The apple black-stem disease was first reported from New Zealand and then from the Union of South Africa towards the end of the nineteenth century. It was then known as a parasitic disease caused by the fungus *Coniothecium chomatosporum*. Now it is known as a non-parasitic disease (potash deficiency) throughout Asia, Europe, England and North America under the names stem-canker, die-back, papery bark-canker, blister-canker, stem-black and branch-blister of apple trees—all of these names meaning one disease only. The disease can be recognized by the slight swellings or blisters of the bark which crack and reveal the presence of sooty moulds which gradually extend from young shoots to bigger branches

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In order to prepare 50 gallons of lime-sulphur enough water is heated in a metallic vessel (must not be copper) to boiling while adding 50 lbs. of quick lime, then 100 lbs. of sulphur is added with constant stirring till the lime is slaked and the sulphur is well broken up. The mixture should be boiled for about an hour until an orange red liquid with a small sediment of lime and sulphur is formed. After straining through hessian cloth this stock solution should be kept in air-tight barrels and must be diluted (1 : 60) before use.

A mixture of calcium polysulphides formed by boiling sulphur and lime together in water is less injurious than the above and is more efficient against the apple scab fungus because it eliminates russetting of the fruit that appears after using Bordeaux mixture earlier in the season.

forming blackish patches. The affected branches die slowly resulting in the unthrifty production of fruits on the trees. The control of this disease may be obtained through potassium manuring and severe cutting of the diseased parts, followed by calcium polysulphide (lime-sulphur) applications or 0.3 per cent Lonacol in a similar manner as recommended for apple scab control, including the springtime treatment. After tree surgery, the cut ends of branches should be smeared with Chaubattia paste[1] or Santar A in order to prevent entry of wound parasites.

White root rot and collar rot of apple and pear are caused by *Rosellinia necatrix* in Himachal Pradesh. This disease is serious in nursery as well as in old plants. Cottony outgrowth and mycelial mats appear in the root system and the collar region so that the severely-affected plants topple over suddenly. When a microscope is available, the pear-shaped swellings near the end of each cell in the hyphal strand of *Rosellinia* are of great diagnostic value. The above-ground symptoms show sparse and wilting foliage and ultimate death of plants. The disease survives as hard, compact, round masses of fungus filaments (sclerotia) on dead wood and in the soil. Though it is difficult to control the disease, precautions can be taken to prevent the spread of the fungus during irrigation or other cultural operations as well as in the movement of the nursery stock. Crab apples *Malus floribunda* and *M. toringoides*, have been found to show considerable resistance to this disease in the U.S.A. They may be used as root stocks for locally-grown apple varieties in order to evolve field-resistant commercial varieties.

Peach Leaf Curl: This disease is of worldwide occurrence but is absent in warm or dry peach-producing areas. It is caused by the fungus *Taphrina deformans* and appears as soon as the leaves emerge. Affected leaves become curled, puckered or distorted

[1] Chaubattia paste is prepared by mixing together into a paste 2 parts red lead (lead oxide); 2 parts copper carbonate and 2½ parts lanoline or raw linseed oil.

and thickened (Fig. 28) and the colour is red to purple in young leaves, turning yellow in older ones. As the season progresses, the red colouration becomes less pronounced, the green colouring matter (chlorophyll) disappears almost entirely and a greyish bloom of powdery coating appears on the affected portion. Later on the leaves are killed and fall down. Thus the vitality of the plant is reduced and the setting of the fruits is seriously affected. Young twigs, blossoms and young fruits may become discoloured, swollen and cankerous. The blighted blossoms wither and drop, diseased fruits are distorted and young fruits soon drop. Older fruits show discoloured, irregular, wrinkled areas on the skin.

The spores of the fungus overwinter on bud scales and bark of young twigs and are washed into the opening leaf buds in the following spring. The disease is favoured by a cool and wet weather when new leaves open, as such the severity of the disease varies from year to year. Because of its simple life-cycle, the disease is easily controlled with sprays of 0.8 to 1 per cent Bordeaux mixture or 0.3 to 0.4 per cent commercial copper fungicides, *e.g.* Blitox-50, after harvest or before the leaf buds swell. It is useless to spray chemicals when the leaves have already opened.

Banana Diseases : The most important diseases of banana are anthracnose in Northern India and Panama wilt and bunchy top in Peninsular India. Serious losses due to rotting of fruit in storage and transit are also reported.

Anthracnose disease of banana is characterized by large brown deep ulcers covered with crimson coloured growth of the fungus *Gloeosporium musarum* on the fruits. Spraying 1 per cent Bordeaux mixture or 0.3% commercial copper compounds such as Blitox-50 with a spreader or 0.1% Fycol 8E is recommended for control.

Panama wilt or banana wilt, first reported from Panama in 1890, is serious in Kerala and Madras and moderate in West Bengal. It appears on the petioles of the oldest leaves as faint-yellow streaks followed by yellowing and wilting until the

Fig. 28
Peach leaf curl

leaf collapses at the petiole. Sometimes the leaves droop without yellowing. Thus there are the yellowing and non-yellowing types of the Panama disease. From the older leaves the disease progresses to younger leaves and within a short period of 4 to 6 weeks, all the affected leaves easily break and hang at the base with only the dead trunk remaining. The fruits, if any, fail to develop. The water-conducting tissues both in the above ground trunk and the underground modified stem (rhizome, Gk, *rhiza*=root) become discoloured and appear as light yellow to brown streaks. When the affected rhizomes are cut open, they show a violet discolouration of the sap-conducting vessels.

The disease spreads by planting infected stock. The fungus invades the roots and proceeds internally to the rhizome, where it develops extensively before passing on to the stem and older leaf petioles. Between the first infection and the appearance of the first symptoms, there may be an interval of 45 days only. The spores of the causal organism *Fusarium oxysporum* f. *cubense* can germinate and cause new infection even after 15 years. The disease is most serious in South America, Africa, India and South-East Asia wherever Gros Michel or other susceptible varieties of banana have been grown for some time. Because the disease is soil-borne, no satisfactory method of chemical control has so far been evolved. The only remedial measures are to use disease-free rhizome stocks and not to plant them in fields with a previous history of Panama wilt. The affected plants should be destroyed and sulphur or lime should be applied in the pits to destroy the pathogen at least from the surface layers. Where new plantations are to be done, the fields should be flooded with 2 inch water to kill the fungus. Basarai variety of banana is known to be tolerant to the disease.

The bunchy top of banana is caused by a virus and transmitted by an aphid. Nearly 30 years ago highly profitable banana production had to be substituted by a low-income agricultural crop in certain areas of Australia due to the severity of destruc-

tion by bunchy top. Now this disease is quite destructive in Assam, Kerala, Orissa, West Bengal and Madras. The leaves of the infected plant become bunched together at the top, the petioles and the leaves become stiff and short and the whole plant remains stunted. Because chemical control of virus diseases is not practicable, the use of disease-free suckers and roguing of infected plants are the recommended control measures.

Banana fruit rot during storage and transit is caused by a complex of saprophytic organisms. The banana trade is as big an export-earner as sugar. It brought to the U.S.A. 62.5 million dollars in 1967. But huge losses caused by banana decay are reported every year from exporting countries. In a recent experiment Du Pont's F. 1991 dip treatments of banana fruit led to the saving of more than 9 million dollars a year in Taiwan's banana export trade to Japan. Recently Dr. Ogawa, a Japanese FAO expert, began tests on a large banana shipment from Taiwan, following the fruit all the way to the markets in Japan. One lot of bananas was treated with the new fungicide (Du Pont's F. 1991), the second lot was dipped in a commonly used fungicide and the remaining third lot was left as an untreated control. The test report says, "After 11 days we found 80 per cent decay in the last, 70 per cent in the second, and essentially no rot or mould on the F. 1991 dip treatments. Even after 18 days, when the fruits were over-ripe for consumption, the decay was very limited." As a banana-exporting country. India may well benefit from Taiwan's experience.

Mango Diseases : Mango is called the king of fruits because of its delicious taste, richness in vitamins and rare sugars, and its relatively low cost which the masses of India can afford. Indian mango pickles and jam are popular throughout the world. Mango suffers from a number of diseases. Mango black tip and mango malformation which are quite serious in India will be discussed here.

Mango black tip is a non-parasitic physiologic disease

confined to the fruits only. It is variously called black tip, tip-rot, and mango-necrosis. It causes serious losses in mango orchards specially in the vicinity of brick-kilns in the States of Uttar Pradesh, Bihar, West Bengal and the Punjab in Northern India. This disease is not common in South India or in any other parts of the world. The disease starts as a small circular, pale area at the tip of the mango fruit and soon enlarges, becomes black and covers the tip of the mango completely (Fig. 29). The outer skin of the affected portion becomes flat and hard. Often the edible flesh underneath this hard black rind is attacked by saprophytic bacteria and is converted into a foul-smelling brown liquid. In the fruiting stage 3 to 4 sprays with a Borax solution of 6 lbs. (2.72 kg.) in 100 gallons (445.6 litres) of water are recommended.

Mango malformation is a serious disease of national importance causing damage in every mango orchard of India. It appears in adult trees where the entire inflorescence is transformed into a compact mass of sterile flowers. Very often numerous vegetative shoots close to each other arise at the apex giving a bunchy appearance. Almost all varieties of mango are susceptible to this disease. The fungus *Fusarium moniliforme* is associated with this disease but further work is necessary to determine if it is directly responsible for the disease. It is also not known whether the fungus spores are carried by the tiny eriophyid mites or the fungus transmits a virus. Unless the nature of this disease is fully understood, no rational control measures can be recommended. Pruning the bunchy tops and other sanitary measures may reduce the incidence of the disease to some extent.

The stem end rot of ripe mangoes can be prevented either by dipping them in aureofungin 100 ppm for 30 minutes or painting Chaubattia paste to stem and scars.

Citrus Diseases : Citrus fruits are rich in vitamin C. Some 20 million tons of fruits are produced in the world. Disease losses are 12.1 per cent of actual production. In view of the importance of citrus diseases in world trade, several books have

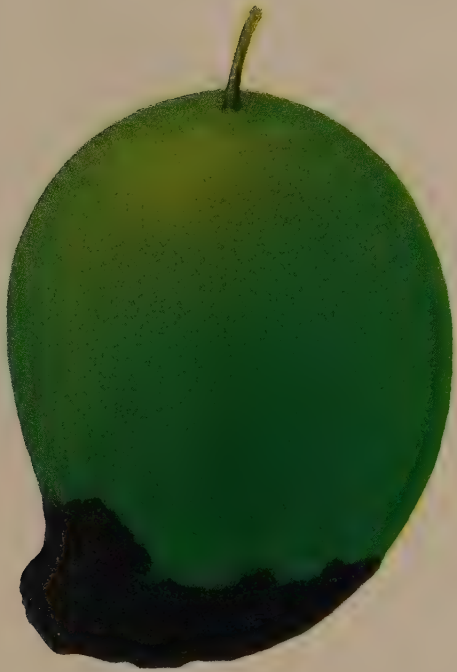

Fig. 29—Mango black tip

(see page 66)

Fig. 31—Citrus green mould

(see page 69)

been written exclusively on this subject. Here we shall discuss only three major diseases: citrus canker, die-back and zinc deficiency.

Citrus canker caused by the bacterium *Xanthomonas citri* is one of the most conspicuous diseases in the citrus orchards of India. Introduced probably from China into America, it established itself between 1908 and 1911 and caused such widespread destruction that in order to save the citrus industry from extinction, the U.S. Government spent more than 2,500,000 dollars in the eradication compaign between 1914 and 1931, excluding the value of 260,000 citrus trees and more than 3,000,000 nursery trees in the State of Florida alone. The disease is characterized by brown, scabby, irregular spots surrounded by dark brown glossy margin on leaves, twigs, older branches and fruits. Leaf lesions first appear as small, round, watery, translucent spots. They are raised and become yellowish brown. The spots initially develop on the lower surface of the leaf and then on both the surfaces. With the progress of the disease, these spots turn white or greyish, rupture in the centre and become rough and corky (Fig. 30). The spots increase in size up to 1 cm. in diameter, often coalescing to form large elongated lesions on fruits and twigs. Premature leaf-fall is caused by such spots on the petioles and midrib of leaves. The disease survives on old branches of the affected trees and spreads in the next rainy season. The only practical method of control is complete destruction of the diseased plants by burning. Since the disease is well established in India, it is not possible to eradicate entire orchards. Therefore the recommendation is to plant disease-free nursery stock in new orchards after spraying them with 1 per cent Bordeaux mixture. In old orchards pruning of diseased twigs and periodical spraying with 1 per cent Bordeaux mixture specially during the rainy season is effective. Recently spraying thrice during the season with 0.01 per cent sodium arsenate and copper sulphate dissolved in water or with Streptocycline 500 1000 ppm. has also been found effective in controlling the disease.

Fig. 30

Citrus canker

Citrus die-back has been known to be caused by the fungus *Colletotrichum gloeosporioides*. In old literature the recorded symptoms are : Young twigs start drying from tip downwards and black dot-like bodies are formed over the dead twigs. A comprehensive report on the survey of this disease in India was prepared in 1967 by a team of workers of the Indian Agricultural Research Institute, New Delhi, based on investigations carried out for a period of five years under a PL-480 project of the American Government. It is established that this disease is prevalent in almost all the States of India and a large number of fungi, nematodes and some viruses were

isolated from different collections. Deficiency of minerals is also recorded. Surely this disease is caused by a complex of factors which have still to be worked out carefully in order to evolve rational methods of control.

Zinc deficiency or mottle leaf of citrus is a physiological disease caused by the deficiency of zinc. The chief symptoms are that the leaves show chlorotic areas situated between the main lateral veins on each side of the midrib and that very small pale, elongated fruits of poor taste are produced on the diseased plants.

Affected trees should be sprayed with 5 lbs. zinc sulphate+ 2.5 lbs. of hydrated lime+40 gallons of water and organic manures should also be applied in bulk.

Citrus green mold and blue mold, *Penicillium digitatum* and *Penicillium italicum*, are more commonly seen in storage or in the market. Green mold infection begins as a water-soaked soft spot on the rind. As the infection enlarges masses of green spores appear and cover the entire surface of the fruit. The rind is wrinkled, the flesh is infected and the fruit becomes soft and shrivelled (Fig. 31). Green mold infects only through wounds, but blue mold may penetrate undamaged rind also. Infection spreads from fruit to fruit in store and packing houses and also within the packing case. Besides citrus and pome fruits, a number of other fruits, corms, bulbs and prepared foods are attacked by other species of *Penicillium*. The antibiotic penicillin is derived from a species of *Penicillium*. Recommended control measures are sanitary packing of fruits in wrappers after a dip in soluble borates or a coating with recommended chemicals and avoidance of wounds and bruises through rough handling in marketing.

Grape Diseases : In all areas of the world where viticulture is practised, plant diseases are of enormous economic importance because failure to carry out control measures as a routine part of the vineyard management always results in such heavy losses that the grower may lose all his investment. The ravages of the downy mildew *Plasmopara viticola* were so

severe in France during the last century that many growers were obliged to take to other professions. But for the chance discovery of Bordeaux mixture by Millardet in 1885, the grape-growing industry all over Europe would have been extinct. According to the statistics of the United States Department of Agriculture, losses of grapes due to diseases during the period 1951 to 1960 were estimated at 959,000 tons or 20.8 per cent of the potential production. The necessity of applying intensive protection to grape culture in India cannot be over-emphasized.

Downy mildew of grapes is one of those historical diseases like wheat rust which are distributed throughout the world. Fortunately epidemics of this disease have so far not been reported in India. The disease starts on the upper surface of the leaves as small, greenish-yellow spots with their margin blending into the darker green of the leaf. Several of these spots coalesce, enlarge and turn brown. In humid atmosphere the corresponding leaf area on the underside of the spot first looks like frost due to the abundance of fungal mycelium (Fig. 32) and later becomes dry and brittle and then drops off. Affected shoots, petioles and tendrils become water-soaked and spongy, the berries rot and the grape bunches shrivel. Cool temperatures between 10°C and 23°C and humid weather are favourable and continued hot and dry weather with plenty of sunshine are unfavourable to disease development. hT edisease recurs from year to year through thick-walled oospores which survive in the soil. Therefore the destruction by burning of all diseased leaves, shoots and berries is the first step in preventing the annual recurrence of the disease. The spread of the disease can be effectively controlled by spraying the vines with 1 per cent Bordeaux mixture or with proprietary compounds in recommended doses. *e.g.*, 0.3 per cent Blitox-50 or Dithane Z-78 first when the shoots are 6 to 8 inches high, again when they are about to blossom, and finally when the fruit is about to change colour. If weather conditions are favourable for the development of an

Fig. 32

Downy mildew of grape

epidemic, at least 6 to 8 sprays will be necessary at frequent intervals.

Here it may be of interest to the common man to know how fungicides have been developed. For a long time school boys harassed the French farmers in the Medoc region by stealing their grapes on vines near the roadside. For the pilferers they found the answer, a poisonous-looking mixture of blue vitriol (copper sulphate) and lime that stuck tenaciously to the leaves when applied with fibre brooms on the vines.

This treatment not only stopped the pilferage of the grapes but also checked the yearly defoliation of the vines caused by the downy mildew. One day, in 1882, as Professor P.M.A. Millardet of the University of Bordeaux walked through the Medok countryside, he observed that there was less mildew on the vines sprinkled with the copper sulphate lime mixture. An idea flashed in his mind. The cure for pilfering grapes may be a cure for the grape mildew also. So he started preparing the mixture in different proportions of these two chemicals and experimented with them on treated and untreated vines. Finally he formulated the famous "Bovillie Bordelaise" or the Bordeaux mixture in 1887. This marked the beginning of the control of plant diseases by fungicides. (Lat. *fungus*=mushroom or mildew+*caedere*=to kill). In 1905, A. B. Cordley introduced lime-sulphur which being too caustic was replaced by "Self-boiled lime-sulphur" by W. M. Scott and T. W. Ayers. The development of a new compound is a tedious and expensive process these days, involving an investment of more than a million dollars or a crore of rupees. Less than one per cent of the many thousands of compounds tested are finally released in the market for general use. Since 1930, many new fungicides for use on fruits and vegetables have been developed in Europe and America.

Powdery mildew of grapes caused by the fungus *Uncinula necator* is found in all parts of the world where grape is cultivated. It is a more serious disease in India than downy mildew. In dry weather, powdery mildew appears in an epidemic form and causes much damage. The French wine industry suffered huge losses due to epidemics of this disease during 1850-1855.

The chief characteristic symptom of the disease is the appearance of white talcum-like powdery patches on the aerial parts of the grape-vine including the fruits. The disease first appears as small whitish patches on the upper or lower surface of the young leaves and later on these patches grow in size and coalesce to cover large areas on the leaves and all

other aerial parts. The powdery white patches turn to grey and finally to dark colour on maturity. Due to the severity of the disease, the vines remain dwarf and appear wilted with malformed aud discoloured leaves, the fruits become undersized or may not be formed at all.

Effective control can be obtained by dusting the vines with sulphur-300 mesh or by spraying 0.3 per cent Karathane. First dusting may be started when new shoots are 3 to 6 inches long, the second just before blossoming and the third dusting 40 to 50 days later.

Grape anthracnose is caused by the fungus *Gloeosporium ampelophagum.* Dark brown, sunken lesions appear on the stem in April and later on in June. Sunken spots, popularly called bird's eye spot, are formed on young fruits.

The disease can be effectively controlled by spraying with Bordeaux mixture (5:5:50) or any other copper fungicide (0.3%) soon after pruning. In case of severe infection, sulphuric acid-ferrous sulphate mixture should be swabbed on the stem soon after pruning instead of spraying.

Guava Diseases: Guava is very rich in the pectinase enzyme and vitamins. It is grown in India for the edible fruit which everybody can afford to supplement his diet with. Two diseases of guava are serious in India : guava wilt and zinc deficiency.

Guava wilt is characterized by the yellow colouration of leaves on terminal branches, death of the affected branch and defoliation. Often symptoms of die-back appear in association with wilt. Researches carried out at Kanpur have shown that this disease is caused by the fungus *Fusarium oxysporum* f. *psidii.* Because the growth of this fungus is favoured in alkaline soil, the intensity of the disease is reduced by the application of 4 lb. gypsum or sulphur applied to root zones of an initially wilting tree. Efforts are being made to prepare wilt-resistant grafts on tested root stocks.

Zinc deficiency of guava is a physiological disease characterised by interveinal leaf chlorosis (yellowness), reduced size

and leatheriness of leaves. Plants remain appreciably stunted with symptoms of die-back and defoliation, production of few or no flowers and drying and cracking of fruits. The disease is most serious in the lighter soils of Rajasthan. Because this disease is due to the deficiency of zinc, sprayings of two bimonthly 0.45 kg. (1 lb.) commercial zinc sulphate plus 319 g. (0.7 lb.) lime in 72.7 litres (16 gallons) of water on the affected plants gives satisfactory control. Young plants respond better to this treatment than the old ones.

Foot Rot of Papaya : It is caused by a complex of soil inhabiting *Fusarium* spp., *Pythium* spp. and nematodes. The disease is also called stem-rot of papaya. Wherever papaya is cultivated, this disease is common. It appears in the rainy season as spongy, water-soaked areas on the bark of the stem immediately above the soil line and leaves become yellow and start drooping and fall down prematurely. As the disease advances, the whole stem is girdled and often spreads on the stem up to 2 feet or more above the ground. The disease is most common in adult trees 2 to 3 years old, but young plants also get affected by the fungus due to early infection and cause damping-off in the nursery. Seedlings obtained from such nurseries when transplanted develop stem rot. This disease needs re-investigation. According to old recommendations published when only *Pythium aphanidermatum* was considered the causal organism, the recommendation for reducing the severity of the disease was to avoid water-logging, roguing and burning of the diseased plants, thorough drenching of the exposed soil around the stem base and also spraying the stem with 6.6:50 Bordeaux mixture or 0.2 per cent Captan (Flit 406). Seed treatment with Agrosan GN and soil treatment with 0.2 per cent Captan were also recommended in the damping-off phase. When studies on the role of *Fusarium*, nematodes and *Pythium* spp. are completed, more rational methods of control will be evolved.

Cashewnut Die-Back : Some 400 years ago, the Portuguese settlers in India introduced the cashewnut tree from South

America. Today India monopolizes the international trade in cashewnuts (seed arils) and shell oil. Cashewnut is one of the most favoured dry fruits in the world. Among diseases, the pink disease caused by *Pellicularia salmonicolor* is usually followed by die-back symptoms of drying up of shoots from the tip downwards. This disease is prevalent all over Southern India. If the dried and diseased twigs are not immediately removed and burnt, the disease may become severe in cashewnut orchards. To prevent further spread of the disease, the cashewnut trees should be sprayed at least once in the season with 1 per cent Bordeaux mixture or 0.3 per cent Copper Sandoz or Dithane Z-78.

CHAPTER VIII

DISEASES OF SUGARBEET AND SUGARCANE

WHAT COAL is to a steam engine, sugar is to man for instantaneous energy. Sugarbeets and sugarcane are grown for sugar — an essential constituent of our daily food and drink. Beet sugar is also in demand for chemical, pharmaceutics, fermentation and heavy industries. At present, over 8.2 million hectares of land is under sugarbeet cultivation throughout the world. Sugarcane occupies enough land within the latitudes of 40°N to 32°S in about 50 countries and more than 491 million tons of sugar is produced. Apart from numerous big farmers, thousands of small farmers in India make a comparatively affluent living by cultivating only a few hectares of land with sugarcane. A big project is under way for the cultivation of sugarbeet in Rajasthan. Both crops lose heavily on account of diseases. According to the 1965 Production Yearbook of the FAO, the specific percentage losses from the actual production of sugarbeet and sugarcane caused by diseases are 13.8 per cent and 42.8 per cent, respectively. In India sugarcane red-rot alone has been responsible for the closure of sugar factories for want of enough cane for crushing during years of red-rot epidemics. The sugarcane variety Co. 475 so popular with growers in Maharashtra State had to be withdrawn in 1955 on account of severe rust attack. We shall discuss here some of the major sugarbeet and sugarcane diseases in India.

SUGARBEET DISEASES

Leaf Spot : Sporadic epidemics of leaf spot caused by the fungus *Cercospora beticola* blight the tops and stunt the root system so severely that the percentage of sugar is markedly reduced. It is a wasting disease which can reduce tonnage and sugar content to the extent that sugarbeet cultivation may become unprofitable. Sprays with fungicides may reduce

disease incidence and spread but the best method of control is to use resistant varieties. In the United States, U.S. 200 X 215 and U.S. 215 X 216 are the resistant varieties which have served the industry well.

Curly Top : This is a virus disease spread by the beet leaf hopper. It caused repeated failure of sugarbeet crops in California until 1926. Thereafter the U.S. Department of Agriculture developed resistant varieties, *e.g.*, U.S. 12, 22, 33 and 34, and also enforced eradication of thistle on which beet leaf hoppers migrate after the beet crop has been harvested. Curly top does maximum damage when seedlings are infected. The young plants are stunted, leaf petioles are shortened and the leaves become smaller, crinkled, and more numerous than in the healthy plant. The roots are exceedingly hairy and the plant may die before the end of the season. In the U.S.A. the curly top virus is known to affect a large number of vegetables also.

Although this disease is not yet of much significance in India, its introduction and spread may be disastrous to our national economy.

Sugarcane Diseases

Sugarcane Red Rot : The red rot is the most destructive disease of sugarcane. Although *Glomerella tucumanensis* is the name of the causative fungus, it is better known by its imperfect stage, *Colletotrichum falcatum*, which actually causes infection of the cane tissues, deterioration of sugar and the rapid spread of the disease. Cultivators dread this disease because of rot of stalks of the standing cane, seed setts, and stubble pieces remaining in the field after harvest. The rotting is made conspicuous by the red colour caused by the oxidation of the damaged tissues. The fungus also produces red to straw coloured long lesions on leaf midribs but isolations from them have not proved so devastating as the light-coloured strains of the fungus obtained from red rot affected stalks. The affected plants can be recognized from a distance by the yellow,

shrivelled and drying crown of leaves. A certain diagnosis of this disease is possible by splitting open the diseased sett or stalk and noting the reddening of the tissues accompanied by cross barring with occasional white or light coloured patches and smell of alcoholic fermentation of cane sugar (Fig. 33). Infection by the red rot fungus may occur at the nodal region, including the buds, leaf scars, and roots during the growing season.

As a sett-rotting disease, red rot is hard to control because the stalk from which seed setts are prepared has been largely affected before the time of planting, and fungicides cannot reach the infected tissues inside a di eased seed sett. Therefore rigorous selection of red rot-free setts is recommended for planting. Seed should always be taken from disease-free nurseries examined regularly by the cane protection staff. Before planting, each sett should be carefully examined for freedom from disease and those setts which show reddening should be discarded.

The spread of redrot can be prevented during the growing season by timely roguing and burning of the affected clumps with utilization of the green leaves for cattle fodder. In no case ratoons of sugarcane should be kept in the red rot-affected fields. Attention should always be given to sanitation by digging out stubbles of diseased clumps and burning them with other trash in the field.

Where facilities are available for hot water treatment of the setts, they can be utilized for controlling red rot. A seed treatment plant has been recently devised in Lucknow by a electrical engineering firm, Vidyut Yantralaya, Lucknow. It has two cages to contain 200 kg. of seed, each to function alternately for treating the setts with fungicides like Aratan (0.25%) to control red rot and pineapple rot diseases. This plant has an automatic timer and a thermostat so that it can be used also for hot water treatment of the setts. The recommendation is that the affected setts should be treated at 50°C for two hours.

Fig. 33—Red rot of sugarcane

(see page 79)

Cercospora personata

Cercospora arachidicola

Fig. 36—Tikka disease of groundnut

(*see page 85*)

The use of sugarcane varieties resistant to red rot is also recommended. Lists of such varieties are published periodically by the State Cane Departments. Some of the varieties found field resistant in Uttar Pradesh are : Co. 975, 1148, 1158, 1336 and 6611; Shahjahanpur selections, Co. S 561, 574. The Bihar varieties B.O. 3, 10 and 47 are also reported to be field-resistant to red rot.

Sugarcane Wilt : Next to red rot, this is the most serious disease of sugarcane specially when found in association with red rot. This disease is found in the West Indies and in most parts of India. The leaves dry up, as if the plant was suffering from drought, followed by the stems which become light and hollow and the cavity is filled with the fluffy, grey and live threads (mycelium; Gk. *mukes* = mushroom or the mesh-like growth of fibres of fungus) belonging to *Cephalosporium sacchari.* Recommended control measures are the use of wilt-resistant varieties of sugarcane such as Co. 1148, 1336, Co.S 109, 541, 562, 568 574 and B.O. 17, 32, 34. Roguing of the affected canes by burning, selection of healthy seed and dipping of seed setts in Agallol-3 (0.5%), Agallol-6, Aratan (0.25%) or any other organo-mercury compound are other control measures against wilt.

Sugarcane Smut : This disease caused by the fungus *Ustilago scitaminea* is recognized by the production from the growing point of a meter long, whip-like shoot (Fig. 34). In ratoon crops, this disease is more severe. When the membrane covering of this smutted shoot bursts, myriads of spores are scattered and infect the axillary buds of the growing plant. Infection also takes place through seed setts so that the germination of buds from infected cuttings is seriously reduced, the affected plant is stunted, and the ratooning ability is weakened. The recommended control measures are: roguing of smutted clumps, careful selection of the smut whips before they break through membranous covering and their destruction either by burning or immersion in boiling water for half an hour and, best of all, use of resistant varieties. Smut-resistant sugarcane varieties

Fig. 34
Smut of sugarcane

recommended for general cultivation in Uttar Pradesh are : Co. 527, 1148, 1336, 6611, Co. S 561 and B.O. 17 and 34.

Sugarcane Rust : The rust fungus *Puccinia kuehnii* produces minute, elliptical orange pustules, later becoming brown on the under-surface of sugarcane leaves. As a result of severe infection, the leaves dry up and there is a general slowing of the photosynthetic (Gk. *photos* = light + *sun* = together + *thesis* = a placing) process and consequent weakening of the sugarcane plant. In spite of the excellent performance of the sugarcane variety Co. 475 in Maharashtra, this variety had to be withdrawn from general cultivation on account of its repeated failure due to severe rust attack. In February, 1956 the attack of rust on a promising sugarcane variety Co. S 510 was so severe over a large tract of 5,000 acres under cane cultivation at Gola Gokaran Nath in Uttar Pradesh that the badly infected fields looked as if they had been burnt.

In the initial stages of the disease when only a few rust pustules appear on the leaves, periodical sprays of 0.2 per cent Dithane is recommended to prevent further spread of the disease.

Red Stripe : This is a bacterial disease of sugarcane characterized by the formation of long, narrow, red longitudinal streaks on leaves and a rot of top shoots. The bacterium *Xanthomonas rubrilineans* is responsible for these symptoms. It has been a serious disease in Queensland, Australia and commonly occurs in many parts of India during the summer and monsoon seasons in India. It is spread by wind and rain. Clipping of diseased leaves, removal of severely affected clumps and application of ammonium nitrate to the soil before the rainy season are the recommended control measures. This disease is of minor importance but it can assume major importance in certain years under favourable weather.

Yellow Spot Disease : The yellow spot disease caused by the fungus *Cercospora koepki* has been known for more than two decades causing damage to sugarcane crops in

India, Burma and more than a dozen other countries. In Andhra Pradesh, this disease reduced raw sugar yield by 25 per cent in 1962.

The most obvious symptom of this disease is the yellowing and spotting of the leaf surface. A dirty-grey fungal growth develops with the reddening on the young fully-expanded leaves. During periods of wet, humid weather, the fungal spores are splashed from the older infected leaves to new infection courts and there is rapid spread of the disease from one field to another. Resistance to the yellow spot disease is fairly common in cane-breeding lines and varieties with satisfactory commercial characteristics are available in most countries.

Grassy Shoot and Twisted Top Disease : This is a disease of virus origin and characterized by excessive tillering, sprouting of lateral buds, poor cane formation specially in ratoon crops, twisting of leaves and thin short internodes (Fig. 35). Manganese-deficiency associated with chlorosis (yellowing) as often found in grassy shoots. In recent years this disease has assumed importance in India and there are frequent banner-lines in newspapers. Control lies in the selection of healthy seed from nurseries prepared during the rainy season, roguing out of diseased stools and where facilities are available, hot water treatment at 50°C for two hours or treatment with hot air at 54°C for eight hours.

Sugarcane Mosaic : The mosaic disease, recognized in the field by the yellowish green streaks on sugarcane leaves, was at one time responsible for enormous losses in Louisiana, U.S.A. and Java. In India, it was estimated that if a 10 per cent infection of leaves caused even 1 per cent reduction in yield, it would mean an approximate loss of the average yield obtained from about 5 million acres. Mosaic of sugarcane is particularly noticeable on variety Co. 313. The introduction of the P.O.J. varieties of sugarcane saved a crisis by this disease in the southern States of America. In India a satisfactory control of this disease has been obtained by bringing into cultivation

some mosaic-resistant varieties such as Co. 282, 285, Co. 331 and Co. 356.

Sugarcane varieties showing field resistance to major diseases in Uttar Pradesh are given in the following Table.

TABLE 3

Showing the behaviour of different sugarcane varieties towards major diseases in Uttar Pradesh

Variety	*Behaviour towards diseases*			
	Red-rot	*Smut*	*Wilt*	*Grassy Shoot*
Co. 356	S	—	—	—
Co. 527	MR	R	S	R
Co. 975	MR	S	S	S
Co. 1007	MR	MR	S	S
Co. 1148	R	R	R	R
Co. 1158	MR	S	R	R
Co. 1336	MR	R	R	S
Co. 6611	MR	R	MR	MR
Co. 6812	S	MR	—	H.S.
Co. S.109	MR	MR	R	R
Co. S.570	MR	S	MR	MR
Co. S.541	MR	S	R	S
Co. S.561	R	R	MR	S
Co. S.562	MR	R	R	R
Co. S.568	MR	MR	R	H.S.
Co. S.574	MR	S	R	MR
B.O. 17	R	S	R	MR
B.O. 32	MR	MR	R	MR
B.O. 34	R	R	R	R
B.O. 47	MR	MR	MR	S

Notes :— R denotes Resistant.
MR ,, Moderately resistant.
S ,, Susceptible.
H.S. ,, Highly susceptible.

CHAPTER IX

DISEASES OF OIL-CROPS

A WELL-BALANCED daily diet may contain 2,000 to 3000 calories (Lat. *calor*=heat). Edible oils have the highest caloric value. They also provide us with reserve energy. Some vegetable oils are industrially important. Therefore great significance is given to oil-crop production throughout the world. The main sources of edible oils in India are groundnut, mustard, rapes, sesame and copra. Linseed oil feeds the paint industry, whereas castor-oil is used for medicinal purposes and lubrication.

It is not easy to make an overall estimate of disease losses in oil crops in India, but according to the 1965 Production Yearbook of FAO, the annual losses due to the diseases of oil crops were 11.7 per cent of the potential value. Corresponding losses in India may be more because the average farmer in India does not pay enough attention to the protection of his oil-crops.

Some of the major oil-crop diseases in India and their control are discussed here.

GROUNDNUT DISEASES

Root Rot of Groundnut : This disease causes much damage in Maharashtra State as well as in other parts of India where this crop is grown. Seedling mortality is heavy and those that survive show signs of root rot and heavy production of small, black sclerotia of the fungus *Sclerotium rolfsii* on the underground parts of the plant, attacking it at all stages of growth from germination to maturity. In severe cases the fungal filaments invade the embryo of the seed, exposing it to the attack of other oil-inhabiting organisms also. The seed surface contamination can be removed by treating the seed with Thiram (1:350) or Captan (1:500) before sowing. But sanitary measures like burning the infected trash and crop rotation, besides

the use of field-resistant varieties, *e.g.*, T 25, Mainpuri local, and T 28 (Uttar Pradesh), are necessary for reducing crop losses.

Tikka Disease of Groundnut: This disease is caused by the fungus *Cercospora personata* which forms small (1—6 mm. diameter), circular, dark brown to black spots, without a yellow halo in the beginning. These are the typical "Tikka" disease spots (Fig. 36) which almost cover the leaf surface during an epidemic of the disease. The spots caused by *Cercospora arachidicola* are circular to irregular in outline, 1—10 mm. in diameter and often coalescing to form larger spots, surrounded by a yellow halo, and can be distinguished from the "Tikka" disease spots. The two kinds of spots occur together. Due to excessive spotting and consequent leaf fall, smaller and fewer nuts are formed, reducing the yield up to 22 per cent. The disease spreads by air-borne spores and survives through the debris of infected plants. Fungicidal seed dressing with Thiram (1:350) or Flit 406 (1:500) before sowing is desirable to prevent Aspergillus seed rot and pre-emergence losses. Spraying the crop with 0.3 per cent Dithane Z-78, Blitox-50, Fytolan, Copper Sandoz or with 0.2 per cent Cosan or Captan (Flit 406) can control the "Tikka" disease. To obtain best results, timely and thorough spraying of the crop should be done.

Groundnut Virus Diseases : Both groundnut mosaic and groundnut rosette diseases are found in India. These diseases are widespread in tropical and sub-tropical Africa and have lately assumed local importance in certain groundnut-producing areas of India. The first symptoms of groundnut mosaic are seen as distinct yellow discolouration of the veins in the youngest unfolding leaves followed by the yellowing of the older leaf tips and specially along the margin. Losses estimated at the I.A.R.I., New Delhi, vary from 23 to 27 per cent.

The rosette disease of groundnut is recognized by the stunting and close tuft of small leaves. The cushion-like plant may be a few inches in diameter bearing a few long branches with similar tufts of small leaves on the tip. Sometimes a mosaic

Fig. 37
Alternaria blight of crucifers.

pattern is also seen on the leaves. The insect vector is the aphid *Aphis craccivora*. Since little is known about the properties of these viruses and insect vectors are not easily exterminated by the application of insecticides, the best method of control is to evolve resistant varieties. In Gambia the varieties Philippine Pink and Philippine White have shown considerable resistance to the rosette disease. Varieties EC 1704, EC 1736, T. 45, T. 11-11, TMV-2 and Pb. No. 1 tested at Kanpur have shown moderate resistance.

Diseases of Mustard and Rapes

Alternaria Blight of Crucifers: The fungi *Alternaria brassicae* and *Alternaria brassicicola* attack mustard, cabbage and cauliflower, causing circular spots up to 1 cm. in diameter with concentric rings and dark growth of the fungus on the leaf spots. On stem, petiole and pods, the spots are elongated (Fig. 37). Radish is attacked by *Alternaria raphani*, which causes somewhat raised, circular to elliptical yellow spots up to 1 cm. in diameter. The affected pods yield shrivelled grains, which germinate

poorly. Invariably the filaments can be found under the seed coat and often invade the embryo also. Because these diseases are internally seed-borne, fungicidal seed dressing is ineffective, except in the case of the blight of radish, where seed treatment with Arasan or Spergon has been found effective. In other crops, seed-borne infection can be eliminated by soaking the seed in hot water at the constant temperature of 53°C for half an hour.

White Rust of Crucifers : The fungus *Albugo candida* is responsible for rust-like pustules on a large number of wild and economic plants, such as mustard, rape, and a number of cruciferous vegetables. These pustules contain a white powder of spores hence the name 'white rust'. All parts of the plant except the roots may be affected and the white or creamy yellow pustules may coalesce to form irregular patches. The leaves and sometimes the entire plant may be dwarfed due to blisters often with scarlet margins extending over several inches on the swollen stem. The flowers become sterile and show discolouration and overgrowth of leafy structures and the seed-setting is poor. The severity of the disease depends on the accumulation of the primary inoculum. Therefore, all heavily-infected living plants and debris should be destroyed by burning. On commercially important crops, sprays of 0.8 per cent freshly prepared Bordeaux mixture or 0.3 per cent copper fungicides such as Blitox-50 are recommended.

Linseed Diseases

The two most important diseases of linseed in India are linseed rust and linseed wilt.

Like wheat rusts, linseed rust also occurs every year in the major linseed-growing areas of India. Even when the linseed crop is moderately affected, bright orange coloured blister-like pustules are conspicuous on the leaves and stems. These blisters are full of an orange powder of spores that easily cause new infections. As the crop ripens, these rust pustules become

reddish-brown and ultimately form black crusts of thick-walled dormant spores. The rust survives on some wild plants as well as on self-sown linseed on the hills and recurs every year in the plains in much the same way as the wheat rusts. Depending on linseed rust intensity, the annual losses may vary from 73 to 100 per cent. Because chemical control of the disease is not feasible, the use of resistant varieties is recommended. Many linseed varieties from the U.S.A. and Australia are immune to rust in India. Some field rust-resistant varieties of linseed are Linseed *Mayurbhanj* in Orissa, Linseed K-2 in the Punjab, R.R. 9, R.R. 38, 488, 491, 1150-5Va, 1198 in Uttar Pradesh with Type 1 for the Bundelkhand region and Type 126 for Eastern Uttar Pradesh. Linseed varieties NP (RR) 9,10, 56, 95, 218, 279B, 279K3, 368, 381, 389, 415 and 501 are also known for their field resistance to rust and can be used for cultivation where they may escape infection and at the same time give high yields.

The wilt of linseed is caused by the soil-borne fungus *Fusarium oxysporum* f. *lini* which infects plants in all stages of growth. In seedlings, the edges of the infected cotyledons roll inwards and die. In young plants the lower leaves become shrivelled and wither away and in mature linseed plants there may be small, ill-defined, dark green or brownish spots on drooping shrivelled leaves which fall ultimately leaving the dry and bare stem standing in the field. With poor pod formation, there is little or no seed-setting. The disease is most prevalent on sandy soils and is favoured by low moisture. Seed dressing with Agrosan GN (1:320) before sowing checks the infection only partially and soil-drenching to kill the fungus in the soil is impracticable. Therefore the best method for preventing the disease is to use wilt-resistant varieties such as R.R. 9, N.P. 12, N.P. 21, N.P. 124, R.R. 5B, R.R. 80, R.R.82, 439, 440, 5, 10, 37, 38, 62, 197, 199, 200 R.R. 202 (1), 272, 328, K1, K2, B.5128, N.P. (R.R.) 5 and N.P. (R.R.).12. Linseed *Mayurbhanj* in Orissa, K-2 in the Punjab and B-37 in West Bengal are also reported to be wilt-resistant.

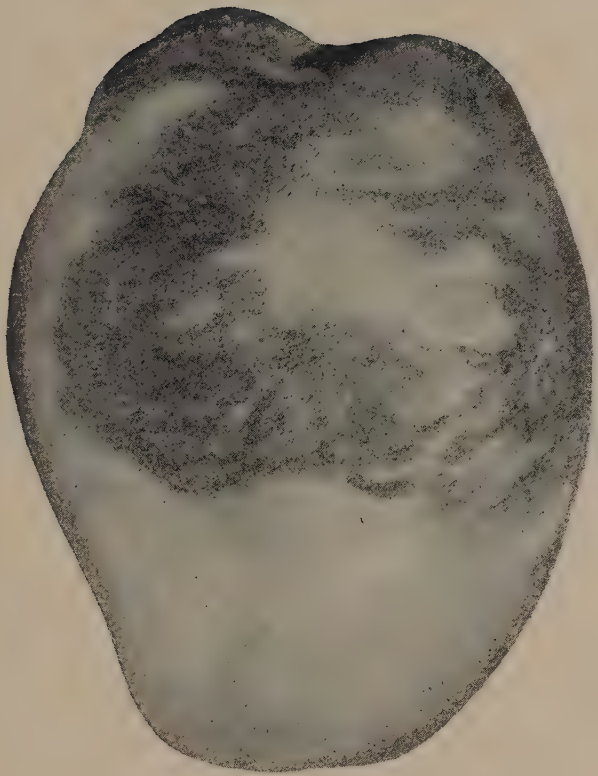

Fig. 19—Potato Late Blight Tuber-rot

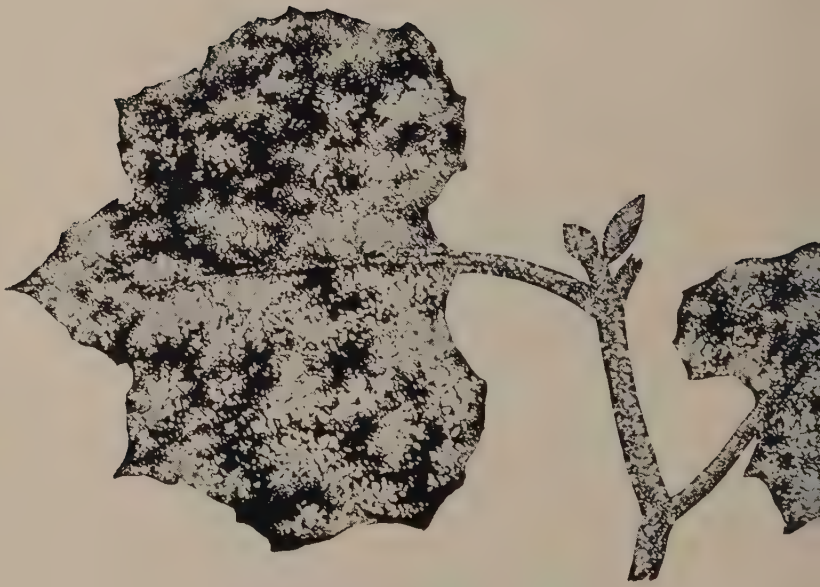

Fig. 26—Powdery Mildew of Cucurbits

Fig. 35—Grassy Shoot of Sugarcane

Fig. 38—Sesame Phyllody

Castor Seedling Blight

Caused by the fungus *Phytophthora parasitica*, this disease is conspicuous by roundish patches of a dull-green colour appearing on young leaves (cotyledons) which droop later on. The plants in seedling stage, when they are 6 to 8 inches high, are more susceptible to this disease. Later the disease proceeds on the petiole and reaches up to the point of attachment with the stem resulting in the hanging down of the affected leaf. Still more damage is caused when the growing point of the plant is involved by the disease. On true leaves the spots are irregular, restricted and brown in colour, not doing much damage to the adult plant. The disease is soil-borne and the fungus may survive in the soil for long periods. The disease is favoured by low-lying, ill-drained fields. Since the disease is soil-borne, no satisfactory chemical control is known so far, still the spread of the disease to older leaves and other plants can be prevented by spraying the crop with 0.3 per cent solution of a dithiocarbamate or copper fungicide in water.

Sesame Diseases

There are two diseases, *Phytophthora* blight and phyllody, which cause much damage to the sesame crop in India.

The *Phytophthora* blight is characterized by extensive areas of water-soaked spots on the leaves and stem. The lesions are brown to begin with, but become black. The discolouration is very marked near the base of the stem, so the affected plants can be recognized from a distance. In humid weather, a woolly growth is formed on the pods, which contain shrivelled brown seed in cases of severe attack. In Gujarat up to 66 per cent crops of two cultivated varieties of Sesame *tal* and *tali* have been known to get affected by this disease. The fungus *Phytophthora parasitica* var. *sesami* is repeatedly isolated from the blighted plants. Seed treatment with 0.3 per cent Captan or Thiram before sowing improves the stand of sesame. For satisfactory control of the disease, field

sanitation and crop rotation to minimise primary infection and several sprays with 0.3 per cent Dithane Z-78 or Bordeaux mixture 3:3:50 on the crop would be necessary.

The sesame phyllody disease is prevalent in all sesame-growing areas of India and causes heavy economic losses. In late season this disease may affect 80 to 100 per cent of plants. The infected plants have shortened internodes with shoots crowded together bearing tufts of small leaves giving a characteristic bunchy appearance (Fig. 38). All flowers are transformed into green, leaf-like structures with distinct vein-clearing. The virus causing the phyllody of sesame is transmitted by grafting and by the jassid insect *Orosius* sp. This disease is not seed-borne and the sesame phyllody virus also affects a large number of weeds. In view of this wide host range and non-availability of a resistant variety, the following indirect methods are suggested to reduce the incidence of the disease: (*i*) the new crop may be sown after burning the trash of the phyllody-affected plants, (*ii*) the crop may be sprayed several times with 0.03 per cent Diazinon soon after the seedling stage, (*iii*) the crop should be regularly inspected to rogue out the diseased plants, and (iv) the crop should be made free from weeds by the use of weedicides. Promising results on the control of phyllody have been obtained recently at Kanpur with two soil applications of Thimet 10 G, (a new granular insecticide of Cyanamid Co.), one at the time of sowing sesame seed and the other after 45 to 60 days at the rate of 10 kg. of the insecticide per hectare (10 lb. per acre). A wild species, *Sesamum prostratum*, is resistant to phyllody. Some crosses have been made at the I.A.R.I. New Delhi, with the cultivated sesame to combine resistance with good yield.

Coconut Diseases

Coconut cultivation extends to about 8,00,000 hectares in India, about 70 per cent of it being in Kerala. Palm kernels or copra yields a valuable multi-purpose oil. In 1965 the copra yield from coconut palms in India was 3,06,258 tonnes. The

coconut tree is attacked by a number of diseases : leaf-rot, anab-e-roga, stem bleeding, bud rot and nut fall and the root (wilt) disease. The total annual world losses are estimated at 40 million dollars or 28.6 per cent of the potential crop.

Leaf rot is caused by the fungi *Gliocladium roseum* and *Helminthosporium halodes*. Affected leaves give a fan-shaped appearance and the shoot rots from tip downwards. Spraying of 1 per cent or 5:5:50 Bordeaux mixture or 0.3 per cent Copper Sandoz or Blitox-50 in March-April, August-September and December-January is recommended to control the disease.

Anab-e-roga is caused by *Ganoderma lucidum*, a root-attacking fungus, which produces large and conspicuous fruiting bodies on the tree trunks. The roots become dry and brittle and a sticky fluid flows from the trunk. Thus the affected tree dies within 2 to 3 years. For controlling this disease, the infected trees are isolated by digging trenches all around and applying sulphur at the rate of 2 lb. per trench. Also sanitary measures are adopted by scooping out the infected portions and applying Bordeaux paste.

Stem-bleeding disease of coconut is characterized by the exudation of a dark red liquid from the cracks in the trunk. The fungus *Ceratostomella paradoxa* is responsible for this disease. It is suggested that in order to reduce the incidence of this disease, drainage should be improved, the affected portions of the stem should be scooped out by a chisel and tar should be applied to the cut surface and copper fungicides, *e.g.* 0.3 per cent Cupravit, Blitox-50 or Copper Sandoz, should be sprayed.

Bud-rot and nut-fall seriously damage both coconut palm and toddy palm in Southern India. The fungus *Phytophthora palmivora* causes discoloured spots on the leaves and leaf bases. Later the central expanding leaf turns yellow and dries up, the growing point is killed, the buds rot (Fig. 39) and nuts fall prematurely with the death of the coconut palm. The accumulation of the infectious material (inoculum) may be checked by cutting down the diseased palms and burning

them. To prevent spread of the disease from infected plants, a spray programme with copper fungicides, *e.g.* 1 per cent Bordeaux mixture or 0.3 per cent Copper Sandoz, Blitox-50, Fytolan or Cupravit should be followed at suitable intervals, depending on local conditions.

The root (wilt) disease, presently confined to the Travancore-Cochin area of Kerala, causes failure of growth and can be recognized by the smaller crown of flaccid, wilting leaves, ribbing of leaflets, breaking of petiole, necrosis of leaf-tips and rotting of the root system. There is an abnormal shedding of immature nuts and in severe cases of the disease no leaves or flowers may be formed so that the affected tree looks like a headless stump. Adult plants at the fruiting stage are more susceptible than seedlings. This disease is as mysterious as the dreaded 'cadang-cadang' (failure of growth) in the Philippines. There is some evidence of a virus infection transmitted by the banana lace wing bug (*Stephanitis typicus*) which commonly breeds on coconut. The virus is soil-borne and infects cowpea and pulses which are often intercultured in the coconut gardens. The rotting of the roots is accompanied by two species of *Rhizoctonia*. Deficiency of some nutrients is also suspected. Unless the nature of the disease is fully understood and rational methods of control are found out, the old recommendations of cutting down the infected trees and burning them should be followed.

CHAPTER X

DISEASES OF FIBRE CROPS AND NATURAL RUBBER

SELF-SUFFICIENCY in food is necessary for freedom from hunger. But our requirements of clothing and other amenities of life must be met with by fibre crops, natural rubber, etc. According to conservative estimates, the annual losses in India from cotton and jute diseases are 10 and 8 to 11 per cent, respectively, of the total production. On a world basis the annual disease losses in fibre crops and natural rubber are : cotton 12 per cent, jute 10 per cent, flax 8 per cent, hemp 5 per cent and natural rubber 15 per cent. Unless intensive plant protection methods are adopted, these losses are a heavy drain on the national economy. In this chapter we shall discuss some of the most important diseases of cotton, jute, sunnhemp and natural rubber and their control in India.

DISEASES OF FIBRE CROPS

Cotton Diseases : Several fungoid diseases, one bacterial and one physiological disease cause more than 10 per cent annual losses to the cotton crop in India.

The wilt of cotton caused by the fungus *Fusarium oxysporum* f. *vasinfectum* is one of the most serious diseases restricted to the black cotton soils of Madhya Pradesh and Maharashtra. These soils are made of heavy clay with an alkaline reaction. The fungus invades one to three week-old cotton seedlings which show yellowing. The overall symptoms of the disease including the discolouration of the tissues and the plugging of water-conducting vessels by the fungus filaments are like the symptoms of *arhar* wilt. Diseased plants are stunted with smaller leaves and cotton bolls. The wilting may be complete or partial, and the leaves become flaccid, turn yellow, then brown and finally drop off leaving the stem bare. The fungus

survives in the soil and on the stubbles of the diseased plants. Soil amendment with zinc increases field resistance to cotton wilt. Besides field sanitation and crop rotation to minimize the accumulation of the fungus inoculum, sowing 'desi' cotton with American cotton is recommended. Wilt-susceptible varieties from India are immune to the disease in the U.S.A. and susceptible American cotton varieties are resistant to wilt in India. The following varieties have been found field-resistant to cotton wilt in India : *Digvijay* in middle Gujarat, *Vijalpa* in Surtee tract of Gujarat, *Jayadhar* in the Dharwar region of Mysore State, *Virnar* in the Khandesh tract of Maharashtra State and *Daulat* in the Marathwada tract of Maharashtra. The Department of Agriculture of Maharashtra claims to have brought cotton wilt under control mainly by replacing all the old varieties with the new field-resistant ones.

Root rot of cotton is another serious disease. The fungi *Rhizoctonia bataticola* and *R. solani* first attack the seedlings which show a soft, yellow patch on the lower portion of the stem. In older seedlings the stem is blackened at ground level. In mature plants the pathogens cause the break-down of the root system of cotton into shreds with yellow slime on the wood. Later black dot-like sclerotia of the parasite are formed on the wood (Fig. 40). Consequently, there is sudden and complete wilting of the cotton plants. Severe incidence of the disease has been observed in the Punjab, western Uttar Pradesh and northern Madras. The development of these pathogens is

Fig. 40
Root-rot of cotton.

favoured by high soil temperatures. Hence early sown cotton intercropped with *moth, Phaseolus aconitifolius*, in order to lower the soil temperatures shows reduced incidence of the disease. Varietal differences in susceptibility to root rot have also been observed. For example, the 'khaki' cotton showed 90 per cent mortality and the Kanpur *desi* variety showed 20 to 30 per cent mortality when these varieties were inoculated with pathogens. The State Departments of Agriculture in India should be consulted for suggesting root rot-resistant varieties of cotton for general cultivation.

Anthracnose exists in all humid cotton-growing areas of the world. The fungus *Glomerella gossypii* (infective stage, *Colletotrichum indicum*) is the primary cause of seedling blight, boll rot, and fibre deterioration. When seedlings are attacked, the stem at the soil level shows a reddish brown discolouration. In this form of attack the spores of the fungus remain adhered to the seed. Therefore, cotton seed should be delinted and dressed with Agrosan GN or Ceresan at the rate of 1:250 before sowing in order to control seedling blight or the well-known sore shin of cotton seedlings. The leaves and stems are frequently attacked especially at wounds but in its commonest form the most prominent symptoms of attack are on cotton bolls as red-brown spots, slightly depressed in the centre, several of these spots may unite to cover almost the entire cotton boll. It is often a serious disease in the State of Maharashtra during March and April. Losses from anthracnose boll-rot have caused 10 to 70 per cent damage to the crop. In the U.S.A., a four-year (1938-1941) survey showed that the anthracnose fungus was isolated from 81.2 per cent of the diseased seedling samples. Two sprays on the seedlings with 1 per cent Bordeaux mixture are sufficient to control the disease.

The angular leaf spot and black arm is a serious bacterial disease caused by *Xanthomonas malvacearum*. The disease appears as seedling infections, boll-rot and gummosis, black arm lesion on the stem and angular leaf spots. These different

phases of the disease can be recognized as small angular water-soaked spots on the under surface of leaves uniting to form large brown or black blotches when dry. On the bolls, round water-soaked, sunken and black lesions and on the stems and fruiting branches, elongated black lesions are formed. In India this disease has been reported from many places in the States of Maharashtra, Madhya Pradesh, Andhra, Madras and the Punjab. During winter rains it assumes a serious form in the State of Madras by stem-breaking, shedding and rotting of bolls and staining of lint. The disease perpetuates from year to year on infected volunteer plants and undecomposed plant debris. If atmosphere temperature is 30°C to 40°C and humidity is 85 per cent, epidemics of this disease may occur. Control measures include such operations as removal and destruction of self-sown plants, seed treatment with Agrosan GN or Ceresan in the ratio of 1:320, late sowing, early thinning, potash manuring and crop rotation.

Jute Diseases : Adequate plant disease surveys have not been carried out in the jute (*Corchorus capsularis* and *Corchorus olitorius*)-growing tracts of India. However, 'seedling blight', 'stem-rot,' 'collar rot,' 'root-rot,' and 'shredding disease' have been commonly observed in jute crops in Assam, Bengal, Bihar, Orissa and Uttar Pradesh which cause heavy losses in the yield and quality of the jute fibre. All these names refer to the nature of damage caused by the fungus *Macrophomina phaseoli*, which is both seed-borne and soil borne. The affected seedlings show damping-off and appearance of blackish-brown streaks on the first leaves. In older plants the leaves turn yellow and fall off leaving the jute plants with bare branches, rotting of stems and roots into shreds. As a result the affected plants finally die. The best method to control the disease is to treat the seed with an organo-mercurial compound such as Agrosan GN, Ceresan, etc., and store them until the next sowing. Since potato is also affected by this fungus, the jute-potato rotation should be replaced by *jute-aman* late paddy or jute-mustard rotations. Under field

conditions 1 per cent Bordeaux mixture or 0.3 per cent copper fungicides (Blitox-50, Fytolan, Cupravit, Blue Copper, etc.) give complete protection from leaf infection. In order to combine earliness and high yield with resistance to stem-rot, selections have been made between the susceptible JRC-142 and the partially resistant D 154 strains of jute.

Other diseases that cause minor damage are 'black band', the fungus *Diplodia corchori* forming a band of sooty spore masses; the anthracnose fungus *Colletotrichum corchori* forming cankerous tissues and chlorosis, light yellow patches on the leaf surface and the variegated appearance of leaves due to a virus. Because of their minor importance, no control measures have been developed for these diseases.

Sannhemp Rust : Sannhemp is an important green manure and fibre crop grown all over India. The rusty pustules of *Uromyces decoratus* appear on all the above-ground parts of the plant leaves, petioles, stem and fruits (Fig. 41). The disease affects the stem more seriously and thus damages the fibre which is used for rope-making and other cottage industries. Much damage due to this disease has been reported from Southern India and also from Bulandshahr and Dehra Dun in Uttar Pradesh. Field resistance to stem infection in cultures U.P. 2-1, Australia N-173 and 843 was observed in November, 1968, at Bulandshahr. The use of resistant varieties is recommended.

Sisal Anthracnose : The true sisal (*Agave rigida*) and other species of Agave are cultivated for fibre in Africa, India and the West Indies. Data on losses are very scanty, but it is estimated that 2 per cent of the potential world production of Agave fibres is lost to diseases. The most important disease of Agave in India and elsewhere is anthracnose, caused by the fungus *Colletotrichum agaves.* A curious blackening and withering of leaves, beginning at the apex and extending downwards, is observed in the diseased plants. Experimental data on the control of this disease are not available, but it is suggested that collection and burning of the diseased leaves and a

protective spray with 1 per cent Bordeaux mixture may reduce the incidence of the disease.

Diseases of Natural Rubber

In all areas of the world where rubber is grown (South America, British Guiana, Africa, Malaysia, Indonesia, Thailand, Ceylon and Southern India), numerous fungal diseases cause considerable damage. The annual world losses of natural rubber from diseases are estimated at approximately 175.4 million dollars (131.55 crores of rupees). Between 1900 and 1911, the fungus *Dothidella ulei* completely destroyed 850 hectares of rubber plantation in Surinam in South America.

Abnormal Leaf-Fall : In India the fungus *Phytophthora palmivora* causes losses varying from 38 to 56 per cent due to abnormal leaf-fall, shoot-rot, patch-canker or bark-canker, black-stripe, black-thread or black-rot and pod-rot. The natural leaf-fall of the rubber plant (*Hevea brasiliensis*) occurs in December and January in South India but in diseased trees there is a second fall of leaves in June soon after the break of the south west monsoon and the defoliated branches often die back in the following cold weather. Soon after leaf-shedding, fruit rot begins. The tapping panel is also invaded by the fungus, resulting in patch-canker, bark-rot and bark-stripe. These symptoms are very clear after the rains. The intensity of rainfall during the months of May to August determines the severity of the disease. Branches showing die-back and old rotting fruits should be carefully removed and destroyed. New leaves can be protected from fresh infection by a prophylactic spray in May with an oil-based copper fungicide, *e.g.* Fycol 8E (1:6) through aerial application or by using low-volume air-blast sprayers (Micron 420 or Mini-micron 77). Depending on the severity of the disease, two more sprays using about 7 to 9 litres of the fungicidal mixture with an interval of 10 to 15 days are also recommended. In order to control the patch-canker or bark-canker stage of the

disease, the rotting bark and coagulated rubber may be scraped and washed well with a solution of Aratan (10 gms. in 4 litres of water) or Ceresan wet (10 gms. in 1.6 litres of water). When the fungicide dries, up a wound dressing compound like wax-rex treseal of Rubberkote may be applied. For controlling the black-stripe, black-thread or bark-rot stage, the tapping panel should be swabbed with Aratan or Ceresan wet solution at weekly or fortnightly intervals depending on the periodicity of tapping during the rainy season. When the fungicide dries up, wax-rex treseal or Rubberkote may be applied on the wounds.

Pink Disease : The pink disease, attributed to the fungus *Pellicularia salmonicolor* has been observed on tea, coffee orange, mango, loquat, apple, etc. which causes the leaves of one or several branches to lose their green colour and formation of whitish or rose-coloured crusts which are often cracked, look like badly dried white-wash on the under side of horizontal branches. On the rubber plant the parasitic stage of the fungus can be easily observed forming a pink crustation on the bark, sometimes extending to a length of several feet. The bark splits and peels away from the wood. Among the susceptible hosts listed above, rubber plants suffer the most, particularly in the age-group of 1 to 3 years when the young stems are quickly 'ringed' and the penetrating mycelium reaches the latex tissues. The main seat of infection is usually at the fork of branches visible from September-October onwards. In early stages of the disease there should be frequent inspection of trees from July to September and Bordeaux paste should be applied 1 foot above and below the affected region. In advanced cases the diseased branches should be pruned off and burnt. Before the appearance of new leaves, protective sprays of 1 per cent Bordeaux mixture should be given.

Powdery Mildew : During March-April an ashy coating of the powdery mildew, *Oidium heveae*, appears on the tender leaves and young shoots. Heavily-infected leaves curl, crinkle and

fall, leaving the petioles attached to the twigs which gives them a broomstick appearance. Soon the petioles are also shed and then follows the die-back of twigs. As a result the infected flowers and tender fruits also drop off, and seed-production is affected. The disease appears more in nurseries and partially wintered trees and survives throughout the year on higher attitudes and shady places. In order to control this disease, 325 mesh sulphur at the rate of 12 kg. per hectare should be dusted 3 to 4 times at fortnightly intervals, commencing from the bud-break stage. Sulphur should be dusted in the early morning hours when the leaves are moist and there is no breeze.

CHAPTER XI

DISEASES OF STIMULANT, DRUG AND SPICE CROPS

'*Eat, drink and be merry*' is an age-old Bohemian proverb, which indicates the natural instinct of all human beings. To prepare delicious food, it must be seasoned with spices like cinnamon, cardamom, coriander, chilli, fennel, ginger and turmeric. Common stimulating drinks are tea and coffee. Tobacco is used daily for chewing and smoking. Because of their importance in daily use, much attention is given to the production or purchase of stimulants and spices throughout the world. What is produced must also be protected from the ravages of pests and diseases.

The total annual world losses due to diseases of some of the stimulant and beverage crops as percentages from the potential crop are of the following order : coffee 16.6, tea 22.8 and tobacco 12.3. The overall loss in production of stimulants in the world are 2.6 million tons valued at 1.7 million dollars (1.275 crores of rupees) or 14.9 per cent of the potential value of these crops. According to estimates made in 1964 by two FAO experts, Drs. Vallega and Chiarappa, the coffee rust (*Hemileia vastatrix*) continued losses up to 70 per cent in Southern India. How useful it is to protect crops from the ravages of diseases by chemical sprays is borne out by the report of an experimental station in India that coffee bushes sprayed regularly for twenty years for controlling brown blight or anthracnose (*Colletotrichum coffeanum*) yielded almost double that of the unsprayed ones. Crop losses from the blister blight of tea (*Exobasidium vexans*) in Ceylon, India, Indo-China, Japan, Java, Sumatra and Taiwan may be up to 30 per cent. Though statistical data on disease losses to drug and spice crops are not available, they seem to be considerable, judging from the reports received in governmental plant protection offices.

Some major diseases of stimulant, drug and spice crops in India and their control are discussed in this chapter.

Diseases of Stimulant Crops

Tobacco Diseases : The diseases that are of concern to the tobacco-grower in India are : damping-off, frog-eye spot, powdery mildew, mosaic and leaf curl, broomrape and sometimes black shank.

Tobacco is a transplanted crop and if seedlings are not raised in well-drained seed-beds, sudden rotting at the collar region and damping-off may destroy them in large numbers. The fungi commonly responsible for damping-off are *Pythium* spp., *Phytophthora* sp. and *Rhizoctonia solani*. In order to control this disease, raised seed-beds should be prepared and drenched with 2:2:50 Bordeaux mixture or a copper fungicide at the rate of 1 lb. in 75 gallons of water (0.45 kg. fungicide in 334 litres of water), 2 or 3 days before sowing the seed which should also be soaked for a few minutes in 0. 2 per cent Blitox-50.

Frog-eye spots caused by the fungus *Cercospora nicotianae* are small brown roundish spots with ash-grey centres up to 2 cm. in diameter which develop on the under-surface and make the leaves unfit for use as wrappers for cigars. This disease is quite common in India. It can be controlled by transplanting disease-free seedlings and spraying them at weekly intervals with 1 per cent Bordeaux mixture or 0.2 per cent Blitox-50 when the crop is 5 to 6 weeks old.

The mosaic and leaf curl diseases of tobacco are of virus origin. Both diseases are widespread in India, mosaic causing more damage in the South, and leaf curl in the North. The Tobacco Mosaic Virus (TMV) has been much publicized in the world since 1935, when Dr. Stanley was awarded the Nobel Prize for crystallizing it, *i.e.* preparing a non-living salt from it, which could in turn reproduce the TMV virus as a living entity. The mosaic-affected plants can be spotted out in the field by their stunted growth and greenish-yellow

mottled leaves with vein-clearing and occasional distortion. It is a highly infectious virus, which can withstand heat up to 90°C and can remain active even in processed tobacco, cigarettes and cigars for more than 25 years. It affects a large number of economic and wild plants but strangely enough it is not transmitted by aphids or white-flies but only through infected juice by mechanical means. Great care has, therefore, to be exercised in handling the nursery seedlings and in field operations by labourers, who should disinfect their hands and tools with Lysol and must not smoke or chew tobacco, while working in the field. The disease is not amenable to chemical control and no disease-resistant varieties have been found. Therefore the only method to mitigate the effects of TMV is to rogue out the affected plants and burn the trash and debris and thus maintain sanitary conditions in the field.

The leaf curl disease is also characterised by stunted growth, leaves becoming small, flowers clustered and curling-up of the entire leaf or portions thereof. This virus is spread in nature by the white-fly *Bemisia tabaci*. Therefore tobacco seedlings can be sprayed twice with 0.04 per cent Parathion in seed-bed followed by more sprays of the insecticide in the transplanted crop in order to keep down the population of white-flies and thereby reduce the incidence of the disease.

Tobacco fields are often infested with the broomrape root-parasite, *Orobanche aegyptiaca*, which bears attractive violet flowers. The habit and control of this parasitic flowering plant have been discussed in the following chapter.

Coffee Diseases : The pilgrim Bababudan is said to have brought seven seeds of the arabica coffee into India around 1600 A.D. on his return from Mecca. The seeds were planted on the Bababudangiri hills named after him near Chikmagalur in Mysore State. In a short time it gained favour as a stimulating drink, particularly in the upper classes of society and was being freely marketed in the bazars of Bangalore and Mysore by about 1800 A.D. Between 1830 and 1870, thousands of

acres were planted on the Western and Eastern Ghat hills in South India and Assam and Bengal hills in Northern India.

In 1871 a few pustules of coffee rust *Hemileia vastatrix* were observed by the planters somewhat as a scientific curiosity. Within a decade it caused a 50 per cent loss in yield and the crop area began to shrink. By 1878 coffee rust had spread to Ceylon, Java and the Philippines where it became a classical example of the ruin of a planting industry. The first symptom is the appearance of small yellowish spots about 2 mm. in diameter on the under-surface of the leaves. When the attack is severe the entire surface may be covered with orange-yellow pustules (Fig. 42) full of spore powder and the affected leaves may turn brown, dry up and fall. The worst damage is usually seen in South India during the rainy season (May to September). The rust rarely occurs on young branches and fruits. Attempts in various countries to control the disease by fungicidal sprayings have not given satisfactory results. Coffee varieties Cultivar '*coorg*' and Cultivar '*kent*' are susceptible, whereas S. 795 has shown considerable resistance. Selections of crosses form *Coffea liberica* x *Coffea eugenioides* have also shown field resistance.

The die-back or anthracnose disease in South India shows premature yellowing and shedding of leaves soon after the rains. The apical bud is killed, internodes are shortened and there is general wilting of leaves, death of twigs and blossom failure. The short internodes followed by vigorous monsoon growth give a 'gooseneck' appearance. Various species of fungi *Colletotrichum*, *Fusarium*, *Phoma*, *Cladosporium* and *Verticillium* have been isolated but none of them is solely responsible for the disease. The root-system of a die-back-affected plant is sparse, showing death or decrease of feeder roots. Though soil application of para-di-chlorobenzene and Dithane Z-78 and foliar sprays with sodium arsenite have failed to show recovery of the affected plant, it is suggested that any treatment which promotes root-growth and provides optimum shade to the coffee plant, would help reduce the die-back damage.

Fig. 39—Bud rot of palm
(see page 91)

Fig. 41—Sannhemp rust

(see page 97)

Fig. 42—Coffee rust

(see page 104)

Fig. 43—Blister blight of tea

(*see page 105*)

Widespread zinc deficiency in coffee has lately been fairly serious in Koppa, Kalasa, Saklaspur (Hanbal area), Bababudangiri, the Gudalur area of the Nilgiris, Wynaad and the Shevroys area of South Indian coffee plantations. On apparently healthy-looking coffee, a cluster of little leaves with thick and extremely brittle leaf blade shows distinct symptoms of malformation. This deficiency is removed within 2 to 3 weeks after spraying 0. 25 per cent zinc sulphate solution (1 lb. in 40 gallons of water or 0.45 kg. in 178.2 litres). In severe cases 3 to 4 sprays are recommended. After the first signs of recovery in the affected plant are seen, the quantity of zinc sulphate can be reduced to ½ lb. in 40 gallons of water and even weaker concentrations of the chemical can be used in subsequent sprays. It may be emphasized that the plants in the marginal lands of coffee should be sprayed first to remove the deficiency symptoms. Meanwhile cultural conditions such as conservation of moisture by mulching and organic manuring should be provided to the coffee plants before spraying them thoroughly with zinc sulphate solution.

Tea Diseases : Some of the diseases that cause considerable damage in the Indian tea estates in Darjeeling, Assam and Southern India are : blister blight, grey blight, *Leptothyrium* die-back and the algal red rust.

Blister blight appears in May as deep red shiny, raised blister-like swellings, bulging out from both sides of the tea-leaf which becomes much curled and distorted (Fig. 43). The growth of the fungus occurs as white patches and the fruiting stage is often grey instead of white. The parasite *Exobasidium vexans* attacks the first flush of 2 to 3 young leaves and kills the young shoots and buds. Thus new growth is largely ruined and in severe cases the tea bush may be permanently damaged. Tea bushes in low, moist and shady localities suffer more. Chemical control of blister blight should be done at several stages : (a) tea in the *plucking stage* is sprayed with nickel chloride, (120-170 gms. in 70 litres of water) per acre or 175 litres of spray fluid per hectare. In a moist-blower use (84 to 120

gms. in 18 litres of water) at the rate of 45 litres per hectare ; (*b*) tea *recovering from pruning*, spray at weekly intervals, copper fungicide-nickel chloride mixture (84 gms. of each chemical in 100 litres of water) per acre with a Knapsack sprayer (250 litres of spray fluid per hectare) or 84 gms. of each chemical in 27 litres of water using 65 litres of the spray fluid per hectare by a mist-blower; (*c*) *young plants in the nursery and first year clearings*, spray at weekly intervals 50% wettable copper fungicide, *e.g.* Blitox-50 (170 gm. in 90 litres of water) per acre with a Knapsack sprayer in clearings or 225 litres of the spray fluid per hectare in clearings ; in a nursery use volume according to requirement. As regards mode of application one row of tea bushes should be sprayed on either side with a Knapsack sprayer and two rows on either side with the mist-blower.

The grey blight of tea is one of the commonest diseases of tea in India. Minute, brownish, irregular spots appear on the upper surface of older and harder leaves. These small spots later on enlarge, turn grey, merge together to form large irregular patches and sometimes cover the whole surface of the leaf. The fruiting bodies of the fungus *Pestalotia theae* are most numerous towards the margin where they are arranged in concentric rings. The old patches of diseased tissue dry up and break away easily. Over-plucking of leaves and red spider attack make the leaves very susceptible to grey blight. The prunings and diseased leaves should be burnt followed by one spray in March and another in June with a protective fungicide, *e.g.*, 0.3 per cent Blitox-50.

The *Leptothyrium* die-back of tea can be recognized by the presence of a few dead branches in the otherwise healthy bushes. The leaves of the affected twigs become yellow, turn brown later on and die from tip backwards. Just above the base of the affected shoots can be seen pinhead-shaped fruiting bodies of the fungus *Leptothyrium theae*. In a section these fruiting bodies are flask-shaped. Diseased shoots should be pruned and burnt and the cut surface of the pruned twigs

should be painted with Chaubattia paste or Bordeaux paste or Santar A. If the surrounding, apparently healthy, shoots are also sprayed with a protective fungicide, *e.g.* Blitox-50 or Dithane Z-78 in the recommended dose, die-back can be appreciably controlled.

The red rust of tea appears in January as reddish brown discs on the upper surface of leaves as a result of infection during the rainy season (July to October). Unlike other rusts caused by fungi, the tea red rust pathogen is an alga (*Cephaleuros mycoidea*) which also occurs on more than 20 other host plants of different families, from ferns to fruit, forest trees and garden plants. In the fruiting stage, this parasitic alga is found abundantly on wood from April to June. Bordeaux mixture (6:6:50) sprayed at the rate of 150 gallons per acre (670 litres per acre or 1600 litres per hectare) immediately after pruning is recommended to reduce the incidence of the disease.

Diseases of Drug Crops

Among the major diseases of drug plants are downy mildew of opium ; powdery mildew, rust and leaf blight of Japanese mint ; leaf spots of Atropa, Datura and Hyoscyamus and wilt, powdery mildew, leaf blight and bud rot of *Rauwolfia serpentina*. It is recorded that the Indian cultivators lost 20 to 30 per cent yield of opium due to downy mildew in 1871. Present-day losses from diseases of drug crops have not been assessed properly, but judging from the scant attention given to their investigation and control, the losses may be considerable.

Opium Downy Mildew : The downy mildew *Peronospora arborescens* occurs every year in a mild form with occasional epidemic out-breaks in large opium-growing tracts of Bihar and Uttar Pradesh. When opium poppy is in flower the disease appears on leaves as pale brown spots, collected near the tip and margin and the attacked areas dry up and wither. In severe attacks, the leaves wither entirely and a fine, grey-violet downy fungal growth can be seen with the naked eye. The pathogen also attacks the Mexican picklepoppy (*Argemone*

mexicana) found near the fields of cultivated poppy in Bengal, Bihar and Uttar Pradesh. Destruction of this weed, followed by protective fungicidal sprays of 0.3 per cent Blitox-50 or Dithane Z-78 on opium poppy, would control the disease.

Powdery Mildews of Japanese Mint and Rauwolfia : The powdery mildews of Japanese mint (*Mentha arvensis* sub. sp. *haplocalyx* var. *piperascens*) and *Rauwolfia serpentina* are caused by the powdery mildew fungi *Erysiphe cichoracearum* and *Leveillula taurica*, respectively. In both cases the first attack is on young and tender leaves. Heavily-infected stems of the Japanese mint shrink and wither within 3 to 4 weeks, causing a reduction of about 20 per cent in oil content. A characteristic symptom of the powdery mildew attack on Rauwolfia is the rolling of leaves with the under-surface covered with talc-like whitish growth of the fungus. Powdery mildews are known to be effectively controlled by spraying with 0.2 per cent Karathane.

Rust and Leaf Blight of Japanese Mint : In June 1960 there was a severe outbreak of rust (*Puccinia menthae*) causing heavy defoliation and poor growth of Japanese mint in Jammu. The Alternaria blight disease is common in Jammu and Kashmir during summer months. The blight infection appears as round to oval brown spots with concentric zones on the upper surface of the leaves, whereas the rust pustules are formed on the lower surface. Consequently leaf-fall is often heavy and the affected leaves show marked decrease in essential oil content. Before the advent of the summer season, one prophylactic and a few preventive sprays with 0.2 to 0.3 per cent Dithane Z-78 would reduce the incidence of both the diseases.

Leaf Spots of Atropa, Datura and Hyoscyamus : Leaf spots mostly confined to the upper surface of Atropa leaves are greyish-white, irregular in shape often merged together to form necrotic areas caused by the fungus *Ascochyta atropae*. Severely spotted leaves dry up and drop off. The disease was noticed in a severe form in September 1959 at the State Drug Farm, Yarikah, Kashmir. In shady localities of the Kashmir

valley, *Ascochyta kashmiriana* causes severe leaf spotting and death of Hyoscyamus leaves. In Jammu, heavy defoliation of medicinal Datura is due to the formation of large necrotic areas by dark-brown, round to oval concentric rings of *Alternaria* sp. Control measures have not been investigated but the incidence of these diseases will be reduced appreciably by a copper fungicide or a dithiocarbamate compound, *e.g.* 0.3 per cent Blitox-50 or Dithane Z-78.

Wilt, Leaf Blight and Bud-Rot of Rauwolfia : For people suffering from high blood pressure, *Rauwolfia serpentina* is extensively used. Therefore, we are interested in protecting it from diseases. By wilting of individual branches and entire plants, about 5 per cent loss to Rauwolfia cultivation has been observed in Jammu. *Fusarium* sp., a soil-borne fungus, has been isolated. Leaf blight and bud-rot, attributed to *Alternaria tenuis*, is common on one-year-old plants. Small brownish spots appear first on tender leaves and as the spots enlarge, the entire leaf may dry up. Top portions of the shoots become purplish-black and bud-rotting is accompanied with the death of the young shoots. No work is reported on the control of these diseases but as in the case of other *Alternaria* diseases, fungicidal sprays may protect the crop. Being a soil-borne disease, *Fusarium* wilt is difficult to control.

Diseases of Spice Crops

The search for a sea-route to Spice Islands of the East led to the voyages of a number of explorers—Columbus, Magellan and many others. India is one of the largest producers of condiments and spices both for home consumption and dollar-earning export. Some diseases of these crops are a major hazard in their cultivation.

Pepper Stump Rot : Caused by *Rosellinia necatrix*, patches of this disease are observed in the extensive plantation on the Malabar coast of India. The leaves turn yellow, soon drop off and the death of the plant is rather sudden. Spread along the roots by strands of sterile fungus tissues is extensive,

chiefly in the soil. Black pepper (*Piper nigrum*) is the most important spice from the point of view of international trade. Therefore, all efforts should be made to control this disease by clearing out old stumps, pruning and painting of cut surfaces by some fungicidal paint, *viz.* Chaubattia paste, trenching to isolate healthy from diseased stumps and other sanitary measures.

Turmeric Leaf Spot : This disease can be easily noticed during the rainy season wherever this crop is grown. Brownish-yellow coalescing spots appear on both surfaces of leaf and in severe cases every leaf is marked by hundreds of such spots, which may be 1 to 2 mm. in diameter. Spraying the crop with 1 per cent Bordeaux mixture or with 0.2 per cent Blitox-50, Fytolan or Dithane Z-78 is recommended to control the disease. These control measures may be practised where economic losses from this disease are heavy.

Coriander Stem Gall and Anthracnose : Galls or tumor-like swellings about 1/8″ broad and up to ½″ long are often conspicuous on the veins, leaf-stalks, peduncles, fruits and other green parts of the coriander plant. These swellings are caused by the fungus *Protomyces macrosporus*. No seeds are formed when the attack is severe. Because no chemical treatments have given satisfactory control, the collection and burning of all gall-affected plants may be feasible in reducing the incidence and severity of the disease. The anthracnose spots appear as concentric rings of black, hairy fruiting bodies on the leaves. The fungus *Colletotrichum capsici* is responsible for the anthracnose spots against which sprays of 1 per cent Bordeaux mixture are recommended.

Cumin Wilt : Caused by the soil-borne fungus, *Fusarium oxysporum* var. *cumini*, cumin wilt losses vary from 5 to 20 per cent in north Gujarat and 5 to 60 per cent in Rajasthan. The average annual loss to the crop in Rajasthan is about 20 per cent. The pathogen may incite pre-emergence death but does not rot the seed. When the crop is about a month old in Rajasthan in January, patches of cumin wilt appear and

within a fortnight the maximum number of affected plants are killed. Wilting, however, continues in a less severe form until March when cumin plants begin to flower. Light soils and soil temperatures ranging between 12°C and 20°C favour the development of the disease. Chemical control is not feasible and none of the indigenous or foreign cumin varieties have so far shown field resistance. However, the incidence of the disease may be reduced if all the wilted plants are collected and burnt and wherever possible long crop rotations are adopted.

Ginger Soft Rot and Thread Blight : Ginger is one of the earliest oriental spices known to Western countries. About 25 per cent of the produce of dried rhizomes (the ginger of commerce) in India is exported to the United Kingdom, the U.S.A., France, Germany and Arabia. Soft rot of ginger rhizomes occurs everywhere in India but the leaf spot and thread blight diseases are predominant in southern India. The soft rot of rhizomes is manifested above ground in July when the tips of leaves become yellow, water-soaked spots appear, the basal portion rots and gradually the whole plant withers and dries. The underground rhizomes become soft, rotten and watery and only the skin of the rhizome is left. Several species of *Pythium* have been isolated but so far *Pythium aphanidermatum* and *Pythium myriotothylum* have proved pathogenic. Ginger leaf spots caused *Phyllosticta zingiberi* appear in September as oval to irregular, water-soaked spots which later become papery. Numerous black, pinhead-shaped fruiting bodies are also seen on these papery leaf spots. In the Malabar district of Madras the thread blight disease caused by another fungus *Pellicularia filamentosa* was responsible for serious damage to the ginger crop in 1953. It is characterized by irregular, water-soaked lesions covering much of the leaf surface. Both young and old leaves are affected which become flaccid and hang down. On drying, the infected portions become white and papery.

Although complete control of these diseases may be difficult, the following measures are recommended to check them

appreciably. Raised beds with a good drainage should be prepared and drenched before sowing with Bordeaux mixture (6:6:50) at the rate of ½ gallon per square foot (16.6 litres per square meter). Then rhizomes selected only from disease-free cultivation should be planted and the crop thus raised should be sprayed to cover both the surfaces of leaves regularly at 2 to 3 weeks' interval with Bordeaux mixture (5:5:50) or 0.3 per cent Blitox-50 or Fytolan, etc.

Cardamom "Foorkey" and "Katte" Diseases : The trade in large or Nepal cardamom (*Amomum subulatum*) and the more valuable small cardamom *Elettaria cardamom* var. *minor*) brings India over 2 crores of rupees annually in foreign exhange. As a carminative and as a spice for flavouring sweet dishes, cardamom is much valued. In Darjeeling, Sikkim and Assam a virus called "foorkey" disease is responsible for the unproductiveness of the large cardamom. The affected plants show a large number of greatly stunted shoots crowding over the rhizomes and bearing leaves much smaller than the normal ones. The "katte" mosaic or marble disease of small cardamom also caused by a virus is confined to the Western Ghats in the States of Kerala, Madras and Mysore. The general yellowing, stunted growth and discontinuous stripes of alternating pale and dark-green streaks running parallel to each other from the mid-rib to leaf margins of the affected plants are conspicuous from a distance. Both diseases are transmitted by the banana aphid (*Pentalonia nigronervosa*) which colonizes the large cardamom during summer and rainy seasons and the small cardamom during the winter months. Because both these diseases spread slowly, it is possible to eradicate completely the disease by a well-organized programme of thorough roguing of infected clumps and replanting with healthy certified seedlings proviously sprayed in seed-beds with (0.15 per cent) Malathion-50 or Metasystox (0.1 per cent) to kill the aphid colonies. Propagating rhizomes should not be substituted for healthy certified seedlings.

Arecanut Fruit Rot or "Koleroga" : A native of Malaya,

the arecanut palm is extensively cultivated in the alluvial soils of Bengal and Assam and the laterite soils of the West Coast. It is used as a mastecatory throughout India. Fruit rot, "Mahali" or "Koleroga" caused by *Phytophthora palmivora* is the most serious disease of arecanuts. Water-soaked patches first develop on young nuts towards the base where the colour becomes darker green and the affected nuts rot and drop-off from the bunches; simultaneously the crown of leaves begins to wilt and dries up. The affected leaves, rotting nuts fallen to the ground and dead trees should be collected and burnt. One pre-monsoon spray in May with an oil-based copper fungicide like Fycol 8E (0.1 per cent) or Bordeaux mixture (5:5:50) followed by more fungicidal sprays from Juneon wards are recommended for the control of this disease.

CHAPTER XII

PARASITIC FLOWERING PLANTS

USUALLY WE think of parasites as tiny plants without flowers, seed or chlorophyll (Gk. *Khloros*=green+*phallon*=leaf), such as fungi and bacteria or the scarcely-visible eelworms (nematodes) which live at the expense of other plants called hosts. A number of flowering or seed-plants are, however, parasitic on economic plants and cause much damage by stealing their food as partial or total parasites. The mildest parasites are those that grow in the soil like normal green plants but absorb their food from the surrounding host plants through minute root connections. The sandalwood tree in Mysore is a typical example of such mild parasitism. Then there are mistletoes (Saxon, *mistltan*=different twig), small and big, which have lost their contact with soil and depend on their hosts for all the water and dissolved minerals. Some of them have green leaves and stem and manufacture their own starch and sugars. These are called partial or semi-parasites.

Some 900 species of mistletoes belong to the botanical family Loranthaceae. About 305 B.C., Theophrastus, the Greek botanist, recognized mistletoe as a parasitic plant. Three centuries ago, the great Swedish botanist, Carolus Linnaeus, described and named the principal European species *Viscum album* because the white berries of the plant were then used in the manufacture of bird lime. This species of dwarf mistletoe is also found in India but it is not economically important. The ancient Europeans prescribed it as an *all heal* for antidoting poisons and a cure for epilepsy. Today it is highly valued for Christmas decorations and for divine blessings on those who stand beneath it.

The complete or total parasites are never green. Their leaves are usually reduced to inconspicuous scales and their functional root-systems are so modified as to develop entirely inside the host tissues.

In this chapter we shall discuss the giant mistletoe (*Dendrophthoe falcata*) and dodder (*Cuscuta* spp.) as partially and entirely-dependent stem-parasites, respectively. Striga (*Striga* spp.) and broome rape (*Orobanche* spp.) are examples of partial and total root-parasites of our economic crops in India.

Stem-Parasites

Giant Mistletoe : The ancient Indians knew this partial parasite of fruit, wasteland and roadside trees by its Sanskrit name *Vrikshabhaksha*, meaning tree-eater. Nearly 60 to 90 per cent mango trees in Northern India and a large number of other trees in different parts of India are moderately infected by the common species of the giant mistletoe, *Dendrophthoe falcata*, formerly known as *Loranthus*. This partial- or semi-parasite can be easily spotted on branches of trees as a dense cluster of small twigs bearing smooth broad leaves, long tubular orange flowers and red berries. The giant mistletoe does not have a root system of its own but develops root-like absorbing organs deep into the tissues of its host so that water and minerals flow from the food-conducting system of the host to the parasite. These peg-like organs embedded in the tissues of the host are called haustoria (Lat. *haustor* = to draw). The green leaves of the parasite manufacture sugars and starch and thus it does not have to depend on its host plant completely. The luscious and attractively coloured berries of the parasite are eaten by birds who wipe off its sticky seed from their beaks on branches of distant trees during their normal flight. On germination the mistletoe seeds establish new infections.

The giant mistletoe can be eradicated by hand-picking in early stages of its growth or by sawing it off from the branches of the host, so that the entire haustorial system is removed. One spray with 30 to 40 per cent diesel oil emulsion in soap water has also been found useful in eradicating the parasite from mango trees.

Dodder : This total parasite belongs to the plant genus *Cuscuta* of which more than 100 identified species are known in the

Fig. 44
Dodder—a total stem parasite

world to attack trees, shrubs, clover, alfalfa, flax, sugarbeets, onion but not cereal plants. *Cuscuta gronovii* is the most common dodder in India conspicuous by its dense tangles of leafless, cream-yellow or orange strands on the hedges, trees and crop plants such as berseem, linseed, mustard, etc. On germination the dodder seed produces thin strand-like stems which grow fast and soon coil round the host plant, simultaneously piercing the host tissues with numerous peg-like haustoria (Fig. 44). On account of this entwining and strangling habit, it is also called strangleweed, devil's ringlet, devil's guts, goldthread, pull-down, hellbine, hairweed, devil's hair and hailweed. Dodder produces clusters of small, white or yellowish flowers and tiny reddish-brown or grey fruits. A single plant may yield 3,000 rough-coated seeds.

Dodder is most frequently carried to the cultivated fields through cattle, farm implements, manure, irrigation water and impure seed. Once established, it usually appears in scattered small patches where it should be cut immediately before it flowers or sets seed. If a crop is heavily infested it should be harvested and burnt at places when it dries up. If conditions permit immune or resistant crops such as cereals, maize, beans or cowpeas should be grown in such dodder-eradicated fields continuously for over five years. Impure seed of farm crops mixed with even a small percentage of dodder seed should be rejected for sowing. Movement of cattle fodder or grazing animals from dodder-infested fields to clean fields should be avoided. Chemical control by weedicides is feasible but not always practicable on account of the high cost involved. Therefore the above preventive and eradicative measures are recommended.

Striga: Also known as witchweed *Striga asiatica, Striga densiflora* and *Striga eusphrasioides* are well known semi-root-parasites of sugarcane, cereals, maize and millets in India. They infest the roots of the host plants from which most of their food requirements are absorbed. Consequently the growth and yield of the affected plants is reduced, the extent of damage depending on the time of infection. Striga is aptly called the "cane-killing weed" because a random examination of poor growth patches of sugarcane in many countries has invariably been connected with striga as a root parasite. In Burma the loss in yield to sorghum crop has been estimated to vary from 4 to 46 per cent. It is on record that under conditions of continuous cropping of sorghum in South Africa, severe infestation by *Striga asiatica* has resulted in the abandonment of land for future farming. These root-parasites belonging to the family Scrophulariaceae of the flowering plants are sometimes 9 inches —2 feet tall and develop in clusters around each clump of sugarcane or sorghum. Parasitism by this weed is confined to the early stages of growth when it remains underground attached to the roots of the host for about

a month. After another three weeks when the weed emerges from the ground, the green shoots bear flowers, fruits and about 100,000 to 500,000 minute seeds per plant. These tiny seeds are dispersed by wind and germinate only in contact with the roots of the host plant which are deeply penetrated by the haustoria.

To control this semi-root-parasite mechanical methods like hand-weeding or ploughing the weed to a depth of 6" to 8" have given indifferent results. But spray applications with selective weedicides, Agroxone (MCPA) and Feronoxone (2,4-D) are effective in killing the parasite. The recommended concentration is 1 lb. (0.45 kg.) of Feronoxone in 100 gallons (445.6 litres) of water. When there is scarcity of water 1 per cent tetrachloro-dimethyl phenoxyacetic acid may be used as dust at the rate of 28 lbs. per acre (31.3 kg. per hectare). In tests carried out in Sudan, control of striga with 2,4-D products increased sorghum yields by 50 per cent in 1963.

Broomrape : The broomrapes appear as clumps of whitish, yellowish, brownish or purplish annual stems arising from the ground at or near the base of their host plants. The stems are 15 to 45 cm. high with bract-like leaves, numerous snapdragon-like showy flowers (Fig. 45) with capsular fruits containing enormous numbers of tiny seeds which germinate in the soil only in contact with the roots of the host plants. Broomrape is the common name of *Orobanche* spp. which are total root-parasites on tobacco, brinjal, tomato (Solanaceae) and mustards, cabbage, cauliflower, turnip, etc. (Cruciferae). Broomrapes have no green tissue and are parasitic by their roots upon the roots of other green plants. When the primary root of a germinating broomrape seed contacts the fibrous root of its host, it forms a nodule of tissue which fuses with the tissues of the host. New roots and a stem of the parasite develop at this point. While the stem emerges above-ground, the broomrape roots form new contacts with other host roots. Thus a large number of parasitic plants appear all over the field at the base of the affected crop plants. In India *Orobanche aegyptiaca* parasitises many crop plants.

Fig. 45
Broomrape—a total root parasite

The best protection against broomrape is to separate the seeds of the parasite mechanically from the crop seed before sowing. It is also recommended that contaminated lots of seed may be treated with a 25 per cent copper sulphate solution which can also be used for spraying the soil. Wherever practicable, long rotations with resistant crops should be practised. Small infections of broomrape can be eradicated by hand-picking the aerial stems before flowering and seed formation.

CHAPTER XIII

FUTURE OUTLOOK

OF ALL THE freedoms required by man, freedom from hunger should have the highest priority. Next come other amenities—clothing, shelter and luxuries of life. Green plants alone can provide these basic necessities to all the peoples of the world. It was estimated that in the mid-1800's about 1,000 million people inhabited the world. By 1920, less than a century later, the population had doubled. Now because of a higher birth-rate and low mortality due to advances in public health, the human population is expected to reach nearly 7,000 million by 2000 A.D. India's human population is over 500 million now. There are 300 million cattle that graze on Indian vegetation. Then there are uncounted millions of monkeys, parrots, locusts, insect pests and plant pathogens and weeds that compete for food with the human and cattle population of India. Together, they rob us of at least 35 per cent of produce from plants.

When population explosion first occurred in the mid-1920's, the progressive countries realized that agricultural productivity depended on the application of science and technology. The traditional method of using bullock and horse power for cultivation on small holdings was given up in favour of mechanized cultivation on larger holdings and the percentage of population engaged in agriculture declined rapidly with an increasing number of people deployed on industries for an all-round economic growth and prosperity. With the continuous increase in agricultural output per unit area, agriculture itself became an industry in well-developed countries. The curves in Figs. 46 and 47 show steadily higher yields of rice and potato per hectare in the U.S.A. during the period 1948-1964 without real harvest failures ever occurring due to pests and diseases or any other natural hazards. During this period, about 7 per cent of the American population was

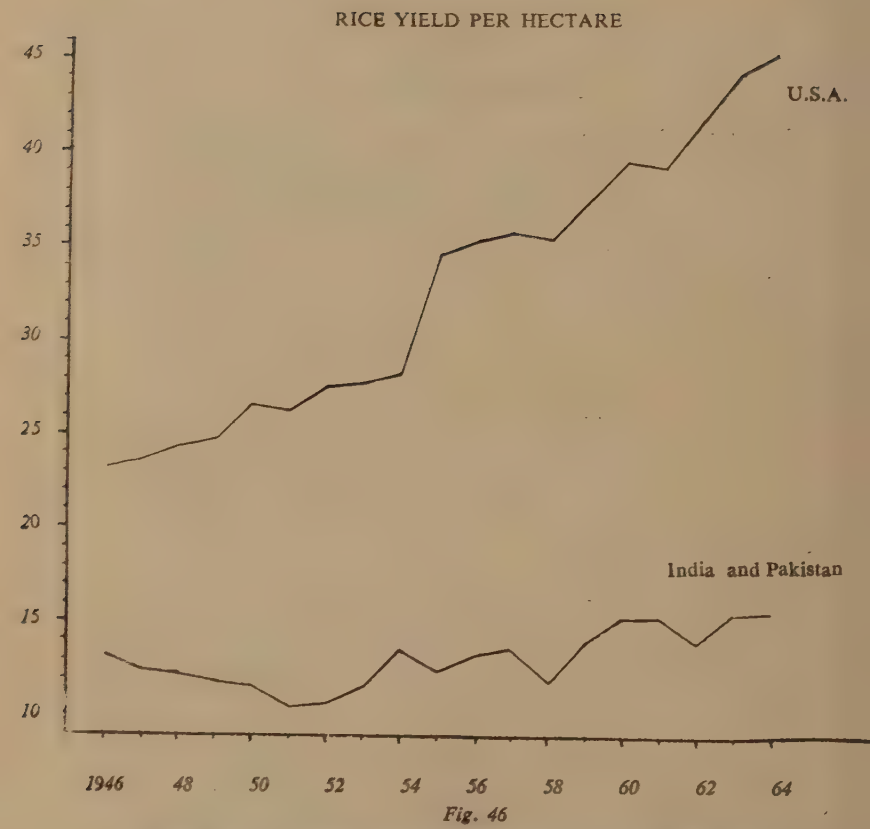

Fig. 46

Trend of rice production per hectare in the U.S.A., and India and Pakistan (after Bayer : *Plant Protection and World Crop Production*, 1957).

Fig. 47

Trend of potato production per hectare in the U.S.A., and India and Pakistan (after Bayer : *Plant Protection and World Crop Production*, 1967).

engaged in agriculture as compared to India and Pakistan's 70 per cent population having agriculture as the only means of livelihood. These regions are also those with the highest population growth and very low crop-yields with frequent crop-failures.

The tragic aspect of plant diseases is that they deform, damage, and kill plants in such large numbers that there are frequent crop-failures in epidemic areas and overall annual losses of over 12 per cent of the Indian national income. In order to overcome this avoidable deficit, the fight against diseases is continuously waged. In the short period of less than a century, measures to control plant diseases have become more precise. High-yielding crop varieties which can resist disease attack have been developed. Bordeaux mixture and lime sulphur which had to be prepared fresh every time often caused injury to leaves, premature leaf-fall and russeting of fruits, if improperly used. Since 1930, they have been replaced by certain ready-to-use or proprietary copper organic combinations. Seed treatment with organo-mercury compounds, *e.g.*, Agrosan GN., Ceresan and Tillex, has given perfect control of a number of seed-borne diseases. The shortage of copper and mercury in the market led to the development of dithiocarbamate fungicides, such as Dithane Z-78, Dithane M-22, Dithane S-31 and Dithane M-45. These are very broad spectrum fungicides which can control downy mildews, rusts and *Alternaria* blights of cereals, vegetables and fruit crops. Thiram as a dust or slurry is extensively used in seed treatment against seed-rot, damping-off, seedling blights, and root-rots of many crops. Captan (Flit 406) has been found very useful for vegetable-seed treatment against pre-emergence and post emergence injuries. A number of soil and seed-borne diseases caused by fungi and nematodes are controlled by soil fungicides such as Brassicol and PCNB and nematicide like Nemagon and Vapam. The dinitrophenolic compounds (Elgetol, sodium 4, etc.) are useful as eradicant sprays for destroying the inoculum on overwintering

or oversummered trash of diseased plants of the previous crops, or for treatment of dormant fruit trees. Trials carried out in South India have shown that Bayer's Antracol is as efficacious as nickel chloride or copper fungicides in the control of blister blight of tea. Karathane wettable powder and liquid are most effective in controlling powdery mildew and mites. Fungicides are ineffective against bacterial diseases. Some potent bactericides like Streptocycline have recently been discovered and show promise in the control of citrus canker and paddy bacterial blight. Valuable information is now available on the relationship of some diseases to weather, making it possible to forecast sudden outbreaks and even warn farmers to undertake chemical sprayings. Developments in the manufacture of plant protection machines have been equally remarkable.

Spoilage of fruits and vegetables during transit and storage can be prevented by previously dipping them for about two minutes in a tank containing a concentration of 1 to 1.25 per cent sodium ortho-phenylphenate. Bleaching powder in a weak watery solution is equally beneficial in cuts, bruises and spoilage of fruits and vegetables. Because these chemicals, insecticides and weedicides show a quick and satisfactory control of pests, diseases and weeds, the annual production of these pesticides is worth more than 1,000 million dollars in the world now. This relatively small expenditure on pesticides shows that the common educated man throughout the world has accepted the challenge, howsoever imperfectly, to fight diseases and other biological depredations to his crops. Plant protection specialists and extension workers can be proud of this achievement.

However, plant diseases are very shifty enemies. Much more must be learnt about their nature and control. The need for controlling plant diseases is far more acute in India than in well-developed countries which produce surpluses. The clearing of land for more farming, direct introduction of new varieties from foreign countries, and the modern practices of

cultivation upset the balance of nature, resulting in mass attacks by parasitic organisms. New diseases and new strains of existing pathogens constantly pose a threat to cultivation in India. Recently some immediate problems of national importance in India have come up. The newly-introduced Mexican dwarf wheats are severely attacked by the fungi *Alternaria triticina* and *Helminthosporium speciferam* whose life-cycle is not completely understood. More information is required on the fungus-nematode complex causing Molya disease in wheat and barley crops and cumin wilt in Rajasthan for devising effective control measures. The Indian cultivators find the available methods of controlling loose smut of wheat and barley quite cumbersome. Researches should be intensified on systemic fungicides (*Oxithin derivatives*) for an easy, chemical control of these diseases. The Helminthosporiose and blast diseases of rice continue to be of major importance. The bacterial blight attacks more severely the newly-introduced high-yielding rice varieties, *viz.*, Taichung Native-1 and IR-8. New downy mildews of maize caused by *Sclerophthora rayssiae* var. *zeae* and *Sclerospora sacchari;* stalk-rot by *Erwina* and *Pythium*, leaf blights due to *Helminthosporium* spp. and mosaic virus transmitted by several aphid vectors have recently posed new threats to maize cultivation. The ergot disease severely affected hybrid *bajra* varieties in Ludhiana in the kharif season of 1967 and ever since, besides ergot, *Piricularia* a blast and smut of *bajra* have also become serious problems over large tracts in India. The recent introduction of new varieties and changes in cropping pattern have brought new diseases into the limelight.

A number of fruits and plantation crops in India also suffer from some serious diseases still shrouded in mystery. The serious citrus decline caused by die-back is now known in India to be a virus-fungus complex. Researches on tissue culture and a programme for bud wood certification need urgent implementation. Mango malformed floral shoots fail to produce fruits and the damage may vary from 50 to 80

per cent in the northern and eastern parts of India. This is another complex disease involving the factors of nutritional imbalance, virus, eriophyid mites and the fungus *Fusarium moniliforme*. Satisfactory control of this malady is not yet available. A number of viruses and the symptoms they cause on fruit, vegetable and plantation crops are recorded in India, but need further investigation. Some serious diseases which await solution for control are : bunchy-top and mosaic of banana, leaf curl and mosaic of papaya, and virus diseases of stone fruits, cardamom, sugarcane, mulberry, coconut and a number of vegetables. Basic information is needed on the relationship of major crop diseases to weather conditions in India to enable forecast of outbreaks and warning service to farmers to undertake timely spraying. Diseases due to non-living agents, *e.g.*, mineral deficiency, soil alkalinity, industrial fumes, etc., need intensive research. Market diseases also cause considerable damage in India but this field of investigation has not been given the attention it merits.

India has chosen the democratic way of life and a non-exploiting social order with equal opportunities for all. The pre-independence "Grow More Food" campaign and the post-independence Five-Year Plans have not yet achieved the expected self-sufficiency in food so that more than two-thirds of the constantly increasing population of India remains hungry and undernourished. Recent researches have shown that malnutritioned childern can also be mentally deficient. It needs no emphasis that agriculture must receive the highest priority. But this has not been so. According to the 1965-66 expenditure on scientific research, 27 per cent of the total funds were allotted to atomic research, 22 per cent to scientific and industrial research and only 7 per cent for agricultural research. Within this meagre and disproportionate allotment of 7 per cent, perhaps the poorest share went to plant pathology. It is well known that first-rate plant pathologists are available in the country but few of them, if any, can hope to be heads of State Agriculture Departments, research institutes, or even

of the plant protection services in India.

Waste is unworthy of a great people. For nearly half a century, plant pathologists in India have fought valiantly against diseases and the fruits of their painstaking research have helped the farmer to save his standing crops and stored plant produce worth billions of rupees. It is possible to increase our crop production by about 10 per cent by controlling plant diseases.

The solution to most problems in our country lies in rapid economic growth for which the common man should not look to what his country can give him but to what he can give to his country. People don't plan to fail—they just fail to plan. With diligence and dedication to productive work by all her citizens, India should soon achieve self-sufficiency in food and basic necessities of life.

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